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SURGICAL ATTRIBUTES*

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At this time I wish to express my appreciation for the honor and recognition implied when you selected me as your president. Serving our organization in this capacity has been a real pleasure. When I call to mind the illustrious surgeons who have preceded me in this office I am filled with humility. I am proud, however, to be a part of such an organization as this, which is stressing the development and progress of younger men. In inaugurating this Congress the founders evidently had in mind the creation of an organization which would give the younger surgeons opportunities to express their thoughts and observations and also, one which would make available an outlet for publication of their papers in the official journal; and at the same time affording the surgeons of the Southeast short, intense postgraduate courses which would give them the latest and best in surgical practice. One cannot attend these sessions without receiving an inspiration and carrying home not only an increase in scientific knowledge but also a determination to do better work. I should like to point out the fact that at the time this Congress was instituted there was no organization in the Southeast which would give these opportunities and there was no surgical journal being published in this area. At that time there were only 220 medical journals in the United States and approximately 22 in the South. Almost all of the latter were state journals. Therefore, I feel we all belong to and participate in a group which is doing much to further the best interest in medicine and to shape the complex human being who is the surgeon of today.

The mechanics of surgery is classed by some as being among the lesser qualifications of a surgeon. One with average dexterity can usually become proficient without great difficulty. As has been stressed on many occasions, the mastery of technic does not make a surgeon. A person with a meager knowledge of the

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fundamentals may become a good operator; to become a good surgeon, not only must the individual be well versed in the basic principles, but he must have developed to a high degree many innate qualities that are not stressed in premedical and medical education. As the years have gone by I have been impressed more and more by the lack of efforts to develop such general basic essentials as the ability to think, judgment, open mindedness, humility and ethics. Many individuals have these qualities to a high degree without having exerted any special effort to acquire them, but in the majority they must be developed. I believe that our present trend in medical education is toward putting too little stress on the need for a better knowledge of languages, history, and philosophy. In our premedical and medical education the student is so busy trying to learn those scientific facts which are placed before him that he does not have time to think on those things which would broaden his mind in all channels.

One cannot become a good doctor without a real interest in medicine. This must be sustained throughout his career; and he must devote himself diligently and faithfully to his profession. Among other things he must study and master the new knowledge appearing in his field. All of this means that we must have a willingness and a desire to work. It has been said that work will make the stupid bright, the bright brilliant, and the brilliant steady. The desire to work, study and think in any line of endeavor increases with our interest in the subject and soon becomes a habit.

Just as important as continuously improving our professional ability is the preservation of moral character and honesty. This contributes greatly to the success of any physician and it is among the greatest attributes of a surgeon. The physician has been trained to accept grave responsibilities, and in the physician the public has placed its confidence and trust. The Hippocratic oath is evidence sufficient that this important feature of medical practice has been recognized by the profession since before the Christian era.

When the Hill-Burton Act became effective and many small but rather well equipped hospitals began to be built in small towns and rural communities, where there were no well qualified surgeons, many in our State were fearful that this would encourage physicians to do work for which they were not qualified and that it would result in much unnecessary and poor surgery. It has been my privilege to observe the work in several of these small hospitals and I am happy to say that on the whole the physicians are very conscientious and are not attempting surgery beyond their ability.

There is only one license given in any state and this permits the physician to practice in any field of medicine or surgery in which he considers himself qualified. Therefore, his conscience must be his guide. Our code of ethics is designed primarily to protect the public by eliminating those physicians who are unworthy or unwilling to accept those principles upon which the proper and satisfactory practice of medicine rests.

Even though there is no legal restraint the medical profession is so controlled by its principles of ethics that public confidence is rarely abused by individuals attempting to do surgical work beyond their capacity. We must acknowledge

a high degree of moral sense and altruism as having been established as a tradition of our profession.

Ambition and enthusiasm are very worthy qualities and fortunate, indeed, is that surgeon who has them to a considerable degree. These qualities have been great factors in the advancement of medical science. Many great discoveries would never have been made without them. Even in the average physician, ambition and enthusiasm play a definite part in his success.

At this time rapid and wonderful strides are being made in the field of surgery through research and clinical investigation. As an example we need, only, to consider the marvelous work which is now being done in cardiovascular surgery. As new discoveries are made and new procedures and methods are evolved we naturally become enthusiastic; but we may become rashly so, and this may lead to difficulties. Our enthusiasm must be tempered by judgment and common sense. Frequently we are tempted to use new procedures which may have been prematurely reported or for which we, ourselves, are improperly prepared. We must never allow our enthusiasm to interfere with the well-being of our patients.

Nature has endowed us with the ability to become creatures of habit. In many respects this is a blessing but, on the other hand, it may become a curse. When carried to a certain degree it may engender laziness, spoil our ability to think, create in us fixed ideas and cause us to become set in our ways. It is easy for our mental processes to follow fixed grooves, but open mindedness is difficult to maintain. It has been said that nothing vitiates judgment and common sense more than the tyranny of the fixed idea.

Often we see surgeons who can carry out a routine operation with comparative ease, but when he encounters something new or unexpected he finds himself in trouble. Our minds must be so trained and our imagination so developed that we can modify our procedures to meet varying conditions.

The attainment of an objective creates in us a sense of satisfaction. If this is repeated frequently enough we may become egotistical. I once heard a great surgeon say that he frequently received letters of commendation from grateful patients and that this praise made him proud and happy; that he occasionally got letters of censure from those who were disgruntled, and these were the letters that were of real benefit to him.

All of us enjoy discussing and reporting our successes, but it is somewhat distasteful to report our failures. A thorough consideration and discussion of our failures makes of us better surgeons and benefits the colleagues with whom we discuss them. Marion Sims reported 12 failures on a vesico-vaginal fistula before he was able to report a success. Our present method of conducting hospital surgical departmental meetings in which we give careful consideration to deaths, failures, complications, and errors in technic and judgment is improving our department, making of us better surgeons and benefiting our patients.

During the past several years the progress made on the scientific side of medicine is certainly amazing, but on the side of art we find that little has been done to make us proud. We now hear much about changes in patient-physician relationship and the bemoaning of the passing of the old time family physician.

These changes, we are told, are at least partly, brought about by an increase in specialization.

My father was a family physician and his practice was in a small town and surrounding rural community. I can remember, vividly, the relationship which existed between him and his patients. He loved all of them and this love was mutual. As a physician they held him in the highest esteem. Many not only sought his medical service but brought other problems which he was never too busy to consider. That which he may have lacked in scientific knowledge he made up in patient relationship.

A few years ago when we came dangerously near complete government control of the practice of medicine we all began to realize that even though we were making rapid progress in scientific medicine we were losing that close personal touch with the public. In an effort to improve the situation, medical organizations from the American Medical Association on down to county medical societies are working hard through public relations committees. Since his election as President of the American Medical Association, Dr. Dwight H. Murray has been stressing the restoration of the close personal relationship between physicians and their patients.

Those of us who are largely treating patients who are referred to us are prone to fail to show the patient that we are sincerely interested in his troubles and problems. Many of our patients come to us completely worked up by their family physicians or an internist or the complete history and physical is done by an assistant or resident and we may spend little time with him. So we do not get to really know the patient, nor does he get to know us. I believe that developing a close personal relationship with our patients is almost as important as the technical procedure. I have found sitting down with him and taking a complete history, in an informal manner, and then doing a physical, even though the case has already been completely worked up, creates a feeling of closeness which I can sense and I am sure my patient does also. Let us never fail to take time to discuss his problems and show a real interest.

To be a good surgeon we must submerge our lives in our profession and the lives of our patients, but it also behooves us to so organize our work that we will have time to be good citizens. It is not sufficient that we only profess our interest in the place where we live and practice; we must actively participate in community affairs as constructive and leading citizens. I am sure that all of us are striving to be good surgeons; but first we must be good citizens.

In closing I should like to quote from Sir William Osler: "The practice of medicine is an art, not a trade; a calling, not a business; a calling in which your heart will exercise equally with your head. Often the best part of your work will have nothing to do with potions and powders, but with the exercise of an influence of the strong upon the weak, the righteous upon the wicked, of the wise upon the foolish.

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SURGICAL TREATMENT OF PULMONARY EMPHYSEMA*

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Increased pulmonary ventilation as shown by increased breath sounds, increased motion of the chest and diaphragm, and increased ability to work and to carry on other activity provides ample clinical evidence to prove the beneficial effects that surgery can achieve for the emphysematous patient whose condition is no longer satisfactorily controlled by medical treatment. This assertion is used in contrast to the opening statement, "The treatment of emphysematous bullae, either medical or surgical, has been so completely discouraging as to prompt a widespread attitude of hopelessness," made by Stringer[16] in the fine presentation of his excellent surgical work showing good results from properly applied surgical technic.

Pulmonary emphysema is not a concise, easily defined disease entity. Clinically and pathologically there are many variables. At one end of the gamut of this disease (fig. 1) there is bronchial asthma and at the other end there is localized cystic disease of the lung.[4] Generalized pulmonary emphysema is found somewhere between these two extremes and is associated with a greater or lesser degree of cor pulmonale. Cystic disease of the lung usually is an extreme degree of localized pulmonary emphysema. It is unfortunate that the condition is confused by emphasis upon the small facets of the over-all problem. The disease may be localized sufficiently in the giant bullae or cysts so that these cases are improperly excluded from the group.[13] There are patients whose first symptoms accentuate cor pulmonale,[9] yet the chest roentgenogram is not interpreted as emphysema. Nevertheless, examination of the patient reveals practically an absence of breath sounds. The proper management of the complete disease entity requires the best possible cooperation between the internist and the surgeon. To arrive at a rational method of medical and surgical treatment the entire problem must be constantly under consideration.

In pulmonary emphysema there is somewhere to be found a beginning of the disease and in the early stage there are no subjective symptoms and no obvious objective signs or findings. If the emphysematous changes are completely localized, as in pulmonary blebs or bullae, there may be definite and easily demonstrated roentgenographic changes. Adequate and persistent medical management in the asymptomatic stage of the disease could prevent progressive development into the symptomatic stage. Surely every effort should be directed toward earlier diagnosis and treatment.

A patient with symptomatic pulmonary emphysema can be described as follows.[5] The patient is usually thin, since it requires considerable effort to

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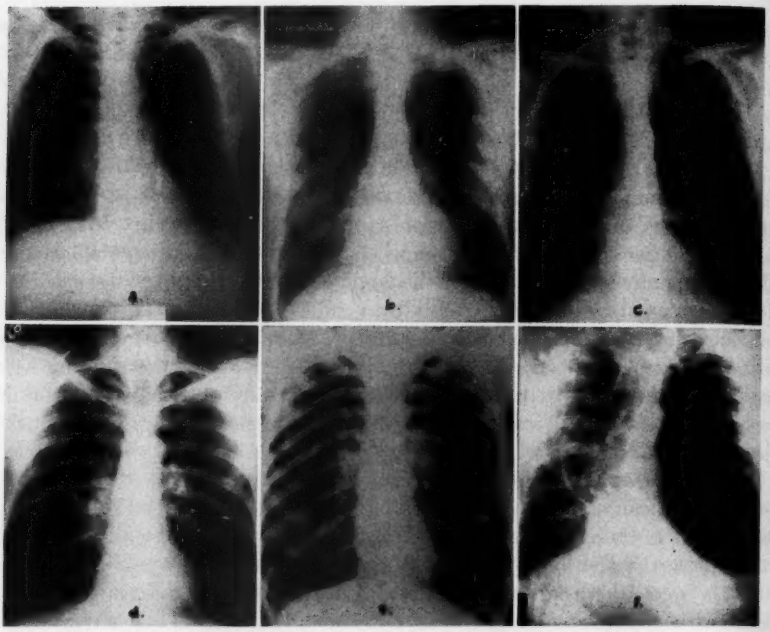

FIG. 1. These roentgenographs show various types of emphysema, illustrating the gamut of disease from asthma to generalized emphysema. (a) A roentgenograph of a patient with asthma. There is no evidence of pulmonary emphysema. (b) A roentgenograph of a patient with generalized emphysema, but at operation it was noted that all areas of the lung were not equally involved by the pathologic process. (c and d) Roentgenographs of emphysema with localized emphysematous cysts which are merely extreme localized areas of emphysema. (e) Roentgenographs of generalized emphysema; compare with b. (f) This roentgenograph indicates an almost purely localized emphysematous cyst which is larger than the pleural cavity and creates a mediastinal hernia into the right pleural cavity. More than 10 years after excision the patient has not developed another emphysematous cyst.

breathe and the shortness of breath makes it difficult to eat properly. He coughs upon awakening in the morning. He expectorates a small amount of tenacious sputum, usually requiring from 1 to 3 hours for it to clear. When the bronchial secretions are removed by cough, the patient is relieved of further cough but he is exhausted. He becomes dyspneic on slight exertion. The amount of exertion possible depends upon the degree and extent of emphysema. He often purses his lips on expiration and leans on his elbows in order to breathe easier. If an upper respiratory infection occurs there is a greater degree of dyspnea.

Upon examination the chest is found to be in a state of expansion or is barrel-shaped. The motion of the chest is limited but equal. Breath sounds are greatly diminished and there is rarely a bronchospastic element. Immediately after cough the breath sounds are further diminished or disappear completely. This finding is characteristic of pulmonary emphysema. The diaphragm moves only slightly as shown by percussion.

A chest roentgenogram discloses a few lung markings. The diaphragm is low

and often flattened, and may show a step-like contour. The ribs are rather far apart, revealing wide intercostal spaces (fig. 1). Fluoroscopy shows reduced motion of the diaphragm and there may be a shift of the mediastinum on inspiration and expiration, thus revealing greater obstruction to air flow in one lung as compared to the other.

In a pathologic study[3] there is noted thinning out of the alveolar walls and septa. Alveolar dilatation is revealed and often there is an alveolar breakdown resulting in coalescence of the alveolar spaces. Coalescence of sufficient broken down alveolar spaces causes cystic-like blebs or bullae. The elastic fibers of the lung disappear and break into fragments. The lung becomes voluminous and thus inelastic, holding the chest in a state of expansion and the diaphragm lower than normal. This condition may be compared to forcing a lung of 7 liter capacity into a 5 liter pleural space (fig. 2). Even in so-called generalized pulmonary emphysema the pathologic changes are not uniform. All areas of the lung are not equally involved by the pathologic process, yet there is rarely any area of lung that can be considered normal. The periphery of the lung is usually more involved than the central portions of the lung (fig. 8c left). The areas of lung showing the greatest pathologic destruction are the most functionally useless areas. Nevertheless, some areas are more nearly normal than others. As the alveolar air sacs become dilated and larger, air cannot leave them as easily. There is increased air pressure in the coalesced, broken down alveolar spaces. This causes compression of the more nearly normal surrounding areas of the lung. The compression is found upon the bronchioles as well as upon the alveoli. The voluminous lung occupies a larger than normal space because of a breakdown of parenchymal tissue, especially the elastic tissue. The voluminous lung with its fragmented and reduced amount of elastic tissue no longer exerts a circumferential pull upon the bronchi. Therefore the bronchi are not held open so widely as normal and during expiration they collapse even more. Normally the bronchi remain open by negative intrapleural pressure that holds expanded the elastic lung, the elastic fibers of which exert a circumferential pulling force upon the bronchi (fig. 3). Thus, the free flow of air is impaired by the tendency of the bronchi to collapse, particularly on expiration. Ordinarily this collapse on expiration is a carefully timed procedure and when it occurs slightly quicker than normally it tends to trap air in the alveoli. This factor found to be greatest in the most diseased areas. Therefore, tidal air is not mixed uniformly.[7] Bronchial spasm, the presence of secretions, and edema or infection of the bronchial wall will further impede or obstruct the flow of air through the bronchi. The result is impaired ventilation as shown by a reduction in maximum breathing capacity and timed vital capacity. Tidal air volume is reduced. A greater amount of residual air and functional residual air is noted. There is an increase in total lung capacity. The enlarged lungs of generalized emphysema actually hold the chest and diaphragm in a state of inspiration.

The capillaries of the alveolar walls undergo degenerative changes and disappear with the breakdown of alveolar spaces. There is reduced blood flow and increased pulmonary artery pressure. The prolonged increased pulmonary artery

pressure gives rise to thickening of the intima, additional reduction of blood flow, and further increase of pulmonary arterial pressure. Thus, a vicious cycle is initiated.[10] The final result is cardiac failure with cor pulmonale. In cardiac failure of this type there is a greater than normal cardiac output.[9]

All phases of the physiology of respiration are altered to a greater or lesser degree. Ventilation is reduced, as indicated by diminished to absent breath sounds and reduced motion of the chest and diaphragm. The passage of gas across the alveolar membranes is impaired, altering the exchange of carbon dioxide and oxygen between blood and alveolar air. Circulation is reduced by degenerative changes in the capillaries, which further interfere with the proper

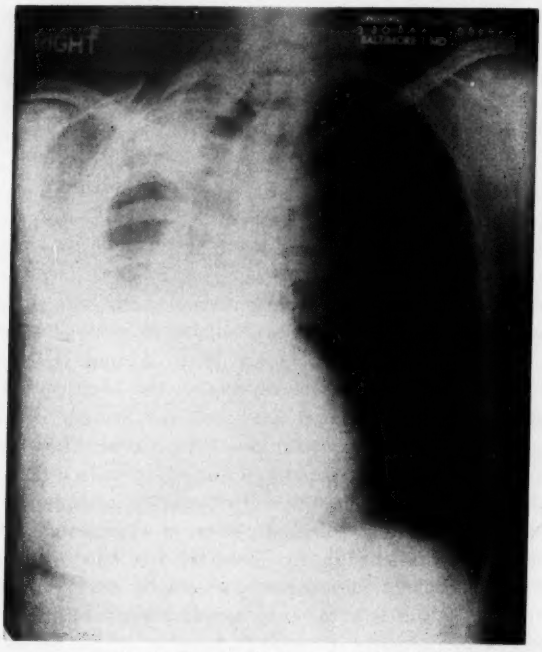

FIG. 2. This roentgenograph of a 61 year old man was taken in 1954, 13 years after a right pneumonectomy for carcinoma of the lung. He has a rather voluminous or overdistended lung. He does not have pulmonary emphysema. In 1957, 16 years after pneumonectomy, his breath sounds are good and there is no dyspnea.

Overdistention of the lung is not necessarily pulmonary emphysema and the same mechanical factors are not at work. There is no breakup of elastic fibers, and there is no breakdown and coalescence of the alveoli. There is increased circumferential pull on the bronchi holding them open (fig. 3), which is exactly the opposite of what is found in pulmonary emphysema.

The roentgenograph of a patient after right pneumonectomy illustrates a left lung that perhaps has increased from a normal 2500 cc. capacity to 3500 cc. capacity but is still 1500 cc. short of equaling the normal pleural capacity. There is still a high negative intrapleural pressure and a strong pull exerted upon the bronchi in a circumferential manner. In the patient with definitely generalized emphysema (fig. 1e) it is much like having the normal 500 cc. lung capacity increased to 6000 cc. capacity and still contained in a normal pleural space of 5000 cc. capacity. The intrapleural pressure is reduced to absent and the circumferential pull holding open the bronchi is reduced or absent.

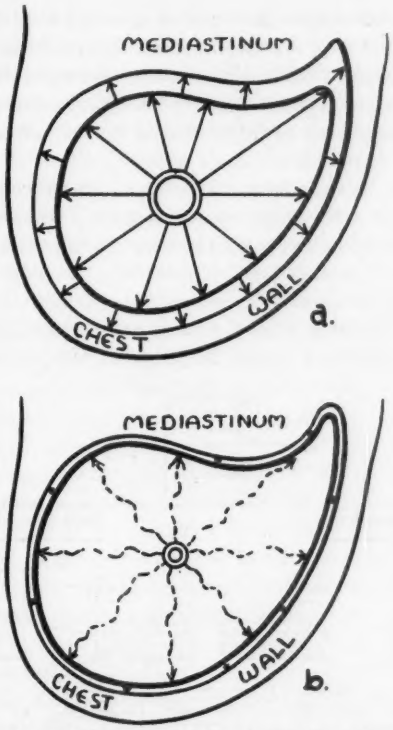

FIG. 3. (a) The drawing illustrates how normal negative intrapleural pressure and the elastic fibers of the lung act together to assert a circumferential pull upon the bronchi, thus holding them open. This action undoubtedly is effective in the normal physiology that causes the bronchi to enlarge in diameter and lengthen on inspiration, and become smaller in diameter and shorten on expiration. In the past years this mechanism was considered to be the dynamic cause for bronchial dilatation in bronchiectasis.

(b) In emphysema of the lung its elastic fibers are for the most part destroyed. The lung is voluminous, occupying a space greater than normal. The normal negative intrapleural pressure is considerably reduced or nearly absent. The pull of elastic fibers is absent. Thus, the normal circumferential pull on the bronchi is absent. The bronchi are not held open. Movement of air through the bronchi is reduced considerably. Air does not readily make its exit from the alveolar spaces.

By surgically reducing the volume of the lung to fit the pleural space once again, the mechanical factor of circumferential pull upon the bronchi is restored to a great degree. The bronchi are held open and movement of air through the bronchi is enhanced, thus providing ventilation of air in the alveolar spaces. The restoration of normal negative pressure within the pleural cavity may also be of some aid to cardiac action.

exchange of gases. There is an altered carbon dioxide and oxygen tension in the blood. In the patient with a severe degree of emphysema there is hypoxia and hypercapnia. Increased carbon dioxide tension in the blood causes a decrease in the chlorides and an increase in the buffer base and bicarbonate of the blood. Only in severe cases is there a slight decrease in the blood pH. These changes affect the respiratory control centers in the central nervous system.[14] The normal control and regulation of the complex phases of respiration are numerous

and complicated. It is not within the scope of this article to discuss the various aspects of respiration, but they are graphically indicated in figure 4. The surgery of pulmonary emphysema probably affects many phases of the complex respiratory control mechanisms. Primarily, however, it affects ventilation of the lungs and produces better and more uniform mixing of the tidal air. It also affects inflation and deflation of the lung.

Patients who have symptomatic pulmonary emphysema will respond to medical therapy in the early stages of the disease.[15] However, when medical therapy is not effective in relieving dyspnea and cough, and when further progression of the disease is not stopped or retarded, the patient should be given the benefits that surgery offers. Of course, the younger the patient and the better the cardiorespiratory system, the more satisfactory will be the results of surgery. Surgery cannot create a new lung, but it can permit lung tissue that

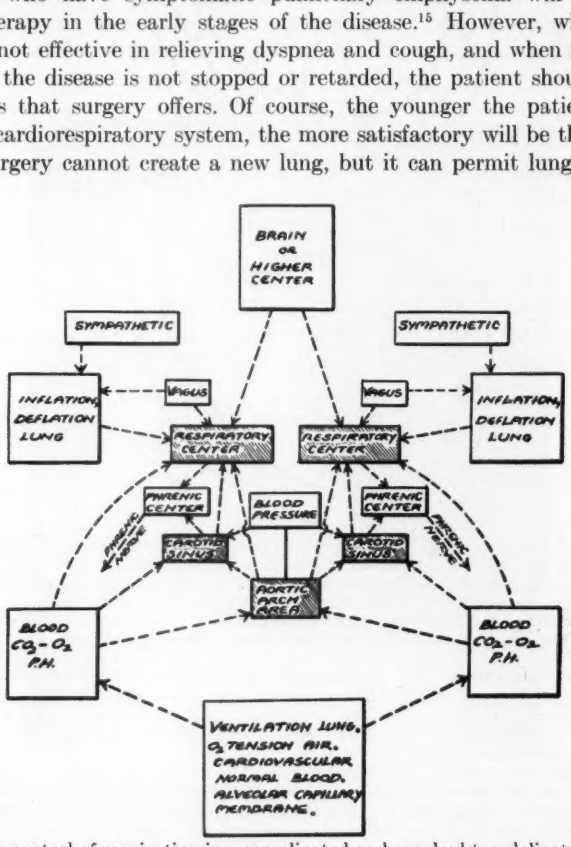

FIG. 4. The control of respiration is a complicated and, no doubt, a delicate mechanism. It can be represented only by a rather complex drawing. A detailed explanation of all the phases of the mechanism of respiratory control is out of place in this description or in this article. However, it is pertinent to the subject of pulmonary emphysema. It is well recognized that minor changes often bring about a surprising relief of symptoms to the patient who is rather dyspneic. The surgical treatment of emphysema directly affects ventilation, the vagus nerve, inflation and deflation of the lungs, and the sympathetic nerves of the lungs. Exactly at which point the relief comes is not definitely known. There is no doubt that ventilation of the lung is increased, but if there is interference with the exchange of gases by changes in the alveolar capillary membrane, this would be of no real benefit to the patient. If the spacial relationships of alveolar-capillary membrane were changed, there might be no need for increased ventilation. This drawing merely indicates the complexity of the problem.

retains a functional capacity to do its work of respiration. Therefore, when the lung is more nearly normal and the disease more localized, the surgical results will be better. If the heart shows signs of cor pulmonale and this is not associated with coronary artery disease or hypertension, there is no contraindication to surgery as long as the patient is not in cardiac failure. The contraindications to surgery are usually to be found in patients above 65 years, in myocardial degenerative disease, especially with hypertension, and in certain associated diseases, particularly bronchiectasis, if it is at all extensive. Cor pulmonale is not a contraindication, provided the patient is not in cardiac failure at the time of operation.

The first stage in the operation is done on the side showing the greater evidence of disease. In about 3 months or later it is carried out on the other side. The patient always receives the greatest subjective relief of symptoms from the first operation. The operation is planned to reduce the volume of the lung by removing the least functioning areas of the lung and by surgically denervating the lung. Lung volume is never reduced by lobe or segmental resection.

The reduction of lung volume is accomplished by the clamp and suture method (figs. 5 and 6). The lung is actually trimmed away by removing as much of the functionally useless areas as is compatible with the lung size or volume desired. If there is a large bleb or bulla it is treated by first incising it on the surface and then by clamp and suture method removing the obviously useless edges (fig. 6). The walls of the remaining space are then approximated by interrupted sutures of atraumatic chromic catgut. This will generally stop all air leaks. It is rare for a particular open bronchus to require individual attention. A lobe or segment as such is never removed because this resection may remove some functioning lung tissue and thus reduce the lung volume beyond the desired size. Since perhaps no really normal lung tissue will be present, it is obvious that the entire diseased lung tissue cannot be removed and this procedure should not be attempted. The volume should be reduced to the point where the lung will fit the pleural cavity. In most cases some of the functionally useless areas of the lung will be retained since these areas act as a filler of the pleural space. In view of the fact that the lung has lost its elasticity, great care must be exercised not to reduce the volume too much because it will not expand and fill the pleural space as normal lung tissue does. This fact is real evidence that the elastic tissue has been destroyed and the lung has become overdistended. Every precaution should be taken to prevent air leaks from the lung since this may lead to serious postoperative complications. Often it is a real task to stop all air leaks from the emphysematous lung because the needle puncture will leak air. It has been found that multiple needle bites with each suture and the incorporation of free bits of muscle, pleura or other tissue in the suture will aid in stopping the air leak. Frequently at the termination of the operation as much as an hour will be spent in tediously searching for and suturing air leaks.

The reduction of lung volume accomplishes three distinct results: (1) It allows expansion and functioning of the more nearly normal areas of the lung since the compressive effects of the useless nonfunctioning areas are at least

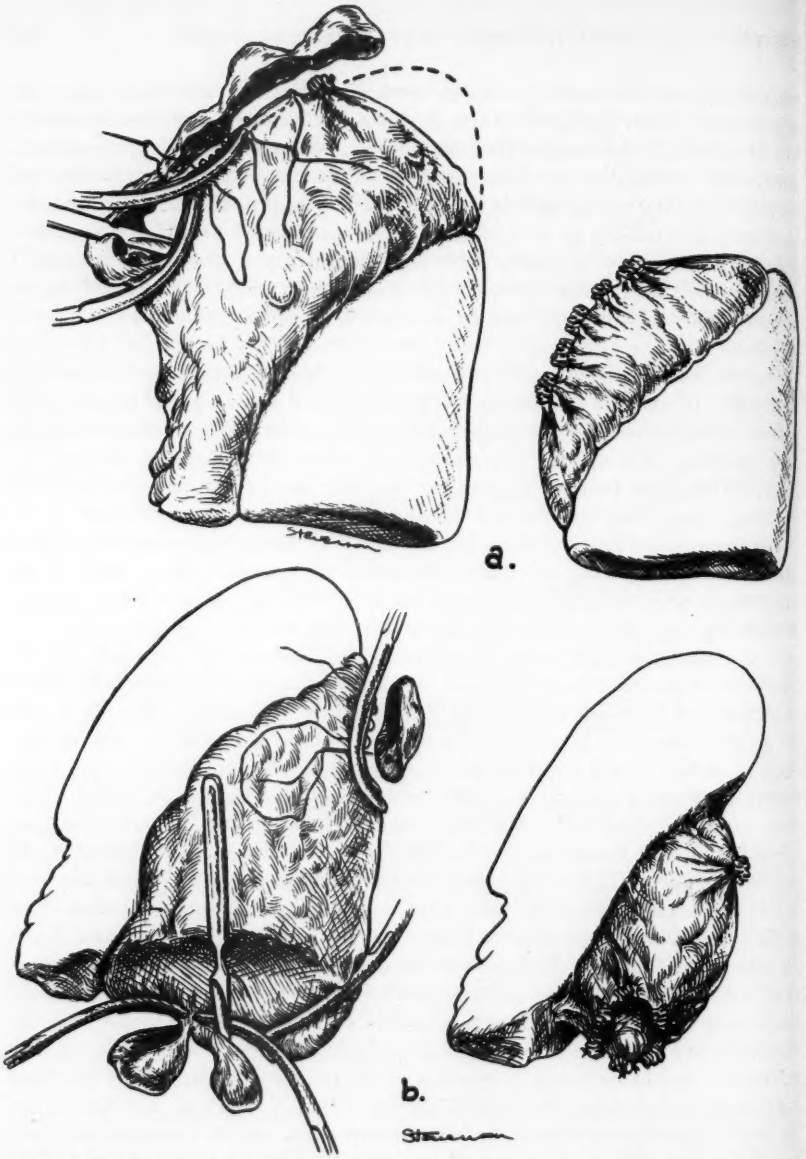

FIG. 5. This drawing indicates a method of reducing the lung volume where there is generalized emphysema. The volume of the emphysematous lung is reduced by excision of the most useless areas. The volume removed by excision does not nearly equal the reduction brought about by suture. The drawings for comparison illustrate in (a) a reasonably normal upper lobe and in (b) a reasonably normal lower lobe. Ideal situations with a reasonably normal lobe are rarely found. When there is fairly uniform involvement of all lobes on a side reduction in volume is brought about by the same method, but both lobes are reduced in size by excising the most useless areas of the lobe. The most useless areas of the lung are always peripheral. Obviously, lobectomy and segmental resection are avoided. It is evident that all the diseased lung cannot be removed. Reduction in lung volume below capacity of the expiratory phase of the pleural space must be rigidly avoided since the remaining lung will not expand like normal lung to fill the space, and thus air leaks from the emphysematous lung cannot be controlled.

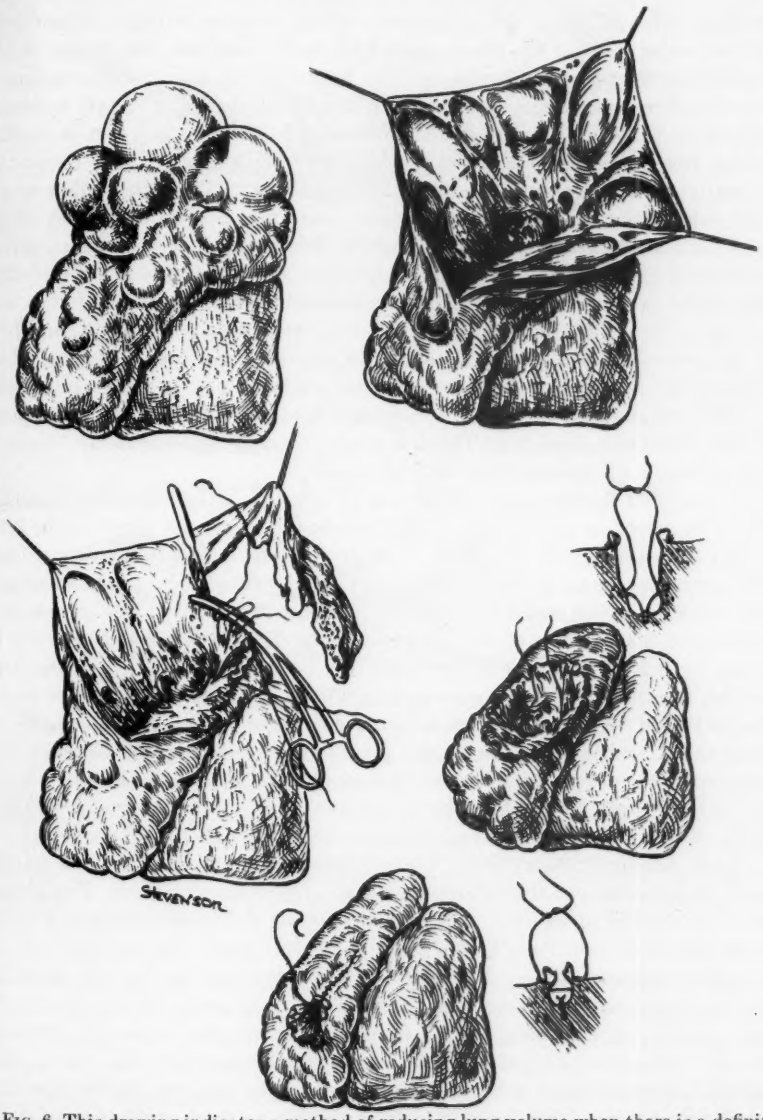

FIG. 6. This drawing indicates a method of reducing lung volume when there is a definite emphysematous cystic area of the lung involved with emphysema. In localized emphysema the surrounding lung is more frequently found in a nearly normal condition. Segmental resection and/or lobectomy is avoided, since again it is obvious that all emphysematous disease cannot be removed and remaining diseased lung will be needed as a filler of the pleural space. The emphysematous cystlike area is incised. The useless areas around the periphery are excised by clamp and suture method and then the remainder of the raw internal aspect of the cyst is obliterated by suturing together its wall. The suturing is carried out in order to avoid air leaks and/or hemorrhage. The individual suture of a bronchus or bronchial opening is an extremely rare maneuver.

partially removed. When the compressive effects are eliminated, air is permitted to flow easier through the tracheobronchial system and into the alveoli. Better capillary blood flow is also effected. (2) Reduction in lung volume restores a more nearly normal negative pressure within the thorax and asserts a circumferential pull upon the bronchi, thus tending to hold them open and to produce a more free or normal flow of air through the bronchi (fig. 3). The restoration of nearly normal negative pressure within the thorax aids venous flow to the right side of the heart. (3) Reduction in lung volume allows elevation of the diaphragm and a less expanded state of the thoracic cage, which in turn permit better motion of the chest wall and diaphragm. All of these results effect better and easier passage of air through the tracheobronchial system and thus into and out of the alveoli of the lung. In this way ventilation is improved considerably as evidenced by a return of normal to nearly normal breath sounds, where formerly the breath sounds were absent to nearly absent. It is also interesting to point out that the breath sounds do not disappear immediately after cough as they did before operation. There is also a reduction in residual air, which in turn increases alveolar ventilation.

The denervation procedure[1, 11] consists of removal of the posterior pulmonary plexus by resection and ligature of all branches of the vagus nerve to the lung, heart and mediastinum. Silk ligature of the cut ends of parasympathetic fibers experimentally seems to prevent regeneration. Only the fibers to the esophagus and lower intestinal tract are spared. A sympathectomy of the periarterial, perivenous, and peribronchial type is done (fig. 7). The bronchial artery is resected in order to remove the sympathetic fibers that it carries to the lung. Neither the thoracic sympathetic ganglia nor the sympathetic trunk are in any was disturbed.[8] The denervation accomplishes three results: (1) It reduces the tenacious secretion of the bronchial glands, thus reducing the cough. (2) It reduces pulmonary artery pressure[12] by capillary dilatation, increasing the circulation and slightly relieving the cor pulmonale. (3) It relieves any bronchial spasm that may be present, thus aiding ventilation.

These data and observations are compiled from the results of operations upon 26 patients and their cases have been reported previously. The present report brings the series up to date.[5, 6] The first operation was done on May 18, 1950 and the last on Feb. 7, 1957. The youngest patient was 16 years old and the oldest 64 years of age; 4 were above 60 years of age and 5 were under 39, the remaining patients being in the 50 to 59 year age group. All except 2 of the patients were male. There were 5 deaths in the hospital following operation. Among those who survived all have been helped except one who died about 4 months postoperatively without being benefited by surgery. Before operation every patient had for a long time been unable to work. Postoperatively 14 returned to some kind of work. Those who have not returned to work show a definite increase in exercise tolerance.

The operative deaths resulted in the following manner. Two died on the hottest day in the summer of 1953, one within an hour of operation and the other on his seventh postoperative day. Two deaths were undoubtedly caused

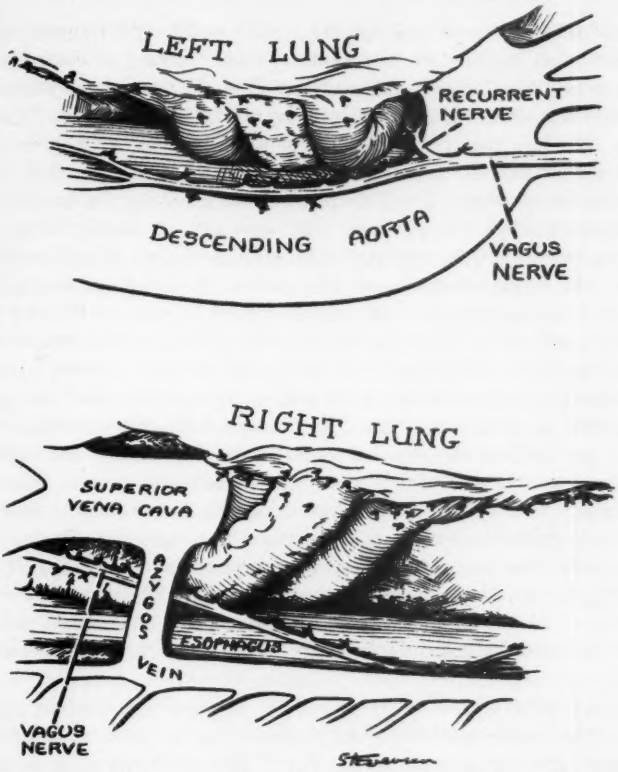

FIG. 7. The method of denervation of the lung is illustrated. All branches of the vagus nerve from the superior aperture of the thorax to the diaphragm, except the recurrent laryngeal nerve, are excised and ligated. This includes the cardiac plexus as well as the posterior pulmonary plexus. The sympathetic ganglia and trunk are not disturbed. However, there is a periarterial, perivenous, and peribronchial stripping, by which a local sympathectomy is accomplished. The bronchial artery is resected since it carries sympathetic fibers to the lung. The pulmonary ligament is excised. When the denervation is completed the lung is attached by the bare pulmonary artery, the bare bronchus, and two bare pulmonary veins.

by insufficient functioning lung tissue. Perhaps if a simultaneous bilateral operation could have been done, the patients would have survived. One of these 2 is included in the 2 who died on the hottest day in 1953. Two patients died because too much lung volume was removed, a mistake in judgment when it was not fully realized that the overdistended inelastic lung would not expand sufficiently to fill the pleural space. It was impossible to control the air leaks since the pleural space could not be obliterated. One patient died of acute suppurative bronchitis, but he was also 1 of the 2 in whom there was too much reduction of lung volume.

After leaving the hospital 4 patients have died. One already described surely died of emphysema without obtaining relief by the surgical procedure. One

patient, aged 53 at the time of operation, died suddenly 26 months postoperatively from what apparently was acute coronary artery disease. He was employed at the time of death. A patient, aged 57 at the time of operation, suddenly died from what appeared to be coronary artery disease about 4 years after operation. He had received considerable improvement in respiratory ability and reserve that did not deteriorate in the 4 years. He was retired from active work before his operation. The fourth death after leaving the hospital was that of a patient, aged 32. He was seen only one time, 3 months after operation. The breath sounds on the operated side were good and he had received much relief from the former dyspnea. He had gained 15 pounds in weight. Although he was urged to have the other side operated upon he refused. He died 18 months after operation and the circumstances of his death cannot be determined.

Bilateral operation is the treatment of choice. However, some patients receive so much relief of symptoms from the first operation that they will not submit to the second surgical procedure. The greatest subjective relief is always obtained by the first operation. The second operation usually increases the pulmonary reserve and accordingly the patient does not receive the same subjective comfort noted after the first operation. Up to the present time there has been no noticeable tendency for the disease to progress on the operated side However, there has been progression on the unoperated side (fig. 8). In 2 patients operation on the second side was delayed until dyspnea occurred once again because of the progression of disease on the unoperated side. These 2 patients experienced the same relief after the second operation as they did after the first.

The beneficial effects of surgery can be easily determined by the obvious increase in the ventilation of the lung as shown by the presence of breath sounds which were formerly absent, by motion of the chest and diaphragm, and by increased exercise tolerance. There is relief from dyspnea that was formerly present. The former harassing morning cough is usually completely relieved.

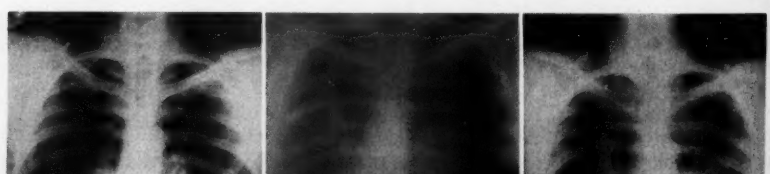

FIG. 8. Roentgenographs of a white male patient, (D. W. S.) (a) before operation, aged 47, (b) 6 years after the first operation, which show no tendency to progression of the emphysematous disease on the operated or right side. However, there is definite progression of the disease on the unoperated or left side. (c) One month after operation on the left side. The patient has received great relief of his dyspnea.

The improvement which these patients experience is accompanied invariably by a definite gain in weight. The dyspnea does not prevent them from eating and all their energy is not consumed in breathing. Of course, the patients are not restored to a normal state but merely given considerable and lasting relief from dyspnea.

It is difficult to predict before operation who will receive the best results. Unfortunately, pulmonary function studies have not been made on many of the patients. However, it is obvious that pulmonary function studies cannot measure the potential lung function that may be restored. In some patients, even though preoperative studies revealed a generalized disease there was found a nearly normal lobe in a collapsed state caused by the compression of an enormously enlarged companion lobe. This condition may be discovered in the patient with a giant cyst or bulla. Thus, the more localized the pathologic process in the lung, the better will be the results of surgery. Laminagraphic studies of the lungs furnish evidence of the good lung tissue and the destroyed lung tissue. Bronchoscopy and bronchography are of great assistance in eliminating patients with associated disease and should always be used if there is any question as to the presence of other conditions, especially bronchiectasis. If associated disease is present and localized, it is in no way a contraindication to surgery, since the removal of the pathologic process can be carried out as a part of the reduction in lung volume. It corresponds to resection of the trigger area of Abbott.[2]

The patient with other pulmonary disease and pulmonary emphysema presents a difficult problem. The prognosis of surgical treatment becomes more difficult. The surgical risk is usually increased. If the associated disease does not occupy too great a volume its excision can be part of the reduction in lung volume and does not add to the risk. For example, the patient with definite pulmonary emphysema and bronchogenic carcinoma confined to one lobe can be subjected with considerable safety to lobectomy and pulmonary denervation, with every reason to believe he will be less dyspneic after operation. This is true only because ventilation is improved. The same is true with other surgical lesions accompanying pulmonary emphysema. It is the belief of the authors that if pulmonary emphysema is encountered during other lung operations, the lesion should be treated in the usual manner and then the emphysema operation should be carried out as described. If the associated disease is one that has contracted and destroyed a lobe and thus reduced its volume, while the remaining lobe has become emphysematous, it is apparent that surgery can offer no aid to the patient unless some type of pulmonary prosthesis, such as the Ivalon sponge, can be added at the time of surgery. The authors have not had the opportunity to use this method.

Obviously, the emphysematous patient who develops a spontaneous pneumothorax and survives long enough to be brought to the hospital should promptly be given the opportunity of an emergency operation of this kind. It surely offers the best chance for survival. During the induction of anesthesia it should be remembered that once an intratracheal tube is inserted the chest can be opened

quickly. This will permit ventilation of the collapsed lung, thus immediately improving the respiratory mechanism.

There are patients who suffer cardiac failure from cor pulmonale as the symptom which first causes them to seek medical attention. By roentgenographic

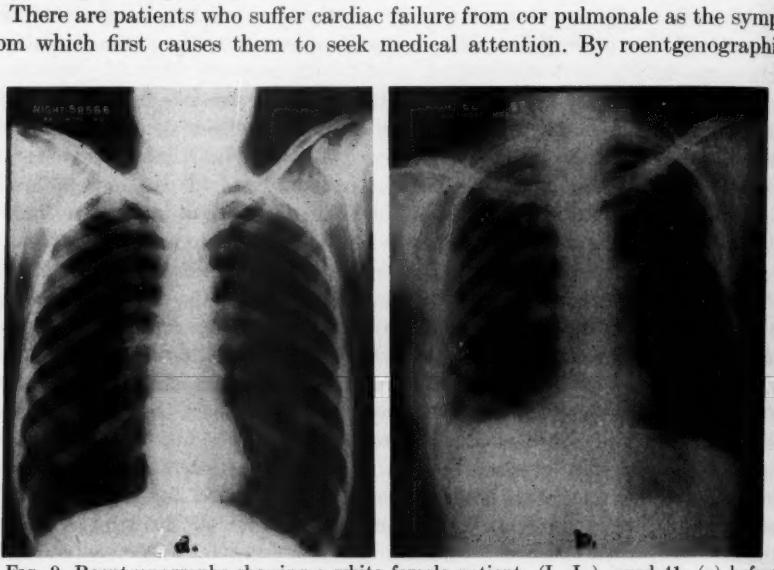

FIG. 9. Roentgenographs showing a white female patient, (L. L.), aged 41, (a) before operation, (b) 26 months after operation on the left side. There has been no tendency toward progression of the disease.

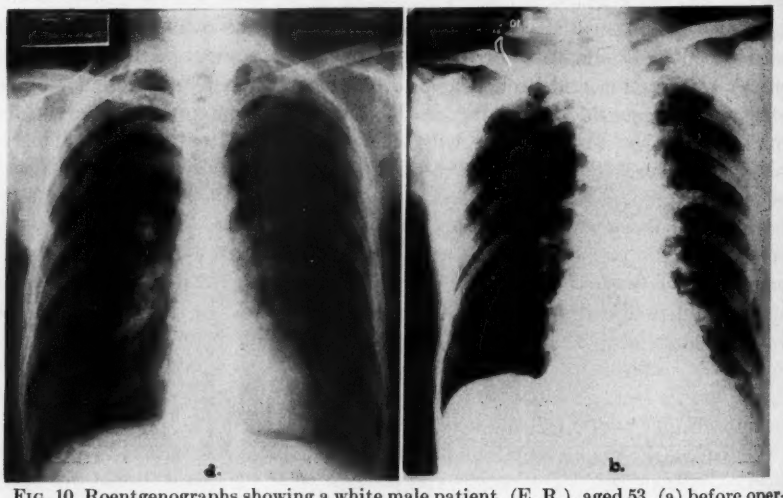

FIG. 10. Roentgenographs showing a white male patient, (E. R.), aged 53, (a) before operation and (b) 2 years after the first operation on the right lung and 2 months after the operation on the left lung.

examination they may appear to have only a minimal amount of emphysema (fig. 10). However, on auscultation of the chest there are practically no breath sounds. Patients of this type are greatly benefited by surgery, but operation should not be done until the cardiac failure has been relieved.

When the series was first studied it was thought that the disease would continue to progress and it would not be long before all the symptoms returned. This has not been the finding (figs. 8, 9, 10). Up to the present time the anticipated natural progression of the disease has not occurred after operation, although the first patient in the group has been followed for 6 years (fig. 8). There appears to be no satisfactory explanation for this unexpected result.

CONCLUSIONS

Pulmonary emphysema is not an easily defined and concise disease entity. There are many variables. It is a condition that is found somewhere between bronchial asthma and localized cystic disease of the lung. When generalized pulmonary emphysema is present, all areas of the lung are not equally involved by tissue destruction. Some areas of the lung function better than others. Some areas have no function and interfere with the function of more nearly normal areas of the lung.

All facets of pulmonary emphysema should be considered with the entire problem. Those with giant pulmonary bullae and those with cardiac failure as the first symptom are as much a part of the emphysema problem as the generally accepted patient with apparent definite uniform bilateral roentgenographic evidence of the disease.

Pulmonary emphysema should be treated by the closest cooperation between the internist and the surgeon. When satisfactory relief of the symptoms is not obtained and when progression of the disease is not retarded or stopped, careful consideration should be given to the benefits that surgery may afford.

Surgery, by reducing the volume of the voluminous, overdistended, inelastic emphysematous lung, causes it to better fit the thoracic cage. Thus, more nearly normal intrapleural negative pressures are restored, the bronchi are normally held open, and better motion of the chest cage and diaphragm is permitted. Denervation of the lung reduces bronchial secretions, reduces pulmonary artery pressure, and relaxes the bronchi. All of these factors improve ventilation and therefore relieve dyspnea.

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OPEN SURGERY OF THE ASCENDING AORTA UNDER HYPOTHERMIA

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At the time this work was undertaken no technic had been developed for direct open surgery of the aortic valves. This objective seemed important. Since completion of the present study,* a number of similar experimental efforts have been reported and it is known that patients have been subjected to open operations upon the aortic valve both under hypothermia and with extracorporeal circulation. Preliminary experiments made several years ago to approach directly the aortic valve under hypothermia were not particularly successful principally because of a high incidence of coronary air embolism and ventricular fibrillation.[3] With improved understanding of the mechanism, prevention and treatment of ventricular fibrillation and better methods for the management of coronary air embolism, we thought that the previous difficulties might be overcome.[5, 6, 7, 9, 10]

MATERIAL AND METHODS

Healthy mongrel dogs weighing between 6½ and 13 kilograms were anesthetized by the intravenous administration of a few cubic centimeters of thiopental sodium. They were placed in a bath of water and crushed ice until the rectal temperature fell to between 30–31 degrees Centigrade. The dogs were hyperventilated with oxygen during the entire experiment and while anesthesia was kept light shivering was controlled by the intermittent administration of a mixture of ether and oxygen. The animals were divided into two groups.

In the first a right thoracotomy was performed through the fourth intercostal space (fig. 1-A). The venae cavae were dissected free and the azygos vein ligated. The pericardium was widely opened over its reflection extending up the aortic arch. The ascending aorta was dissected free from its fat pad and an umbilical tape was passed around it The right superior vena caval atrial junction was infiltrated with 1 per cent procaine hydrochloride until the characteristic slowing and pinking of the heart indicated a successful blockade. The vena cavae were occluded with Potts ductus clamps and 1 minute later the ascending aorta was cross clamped with a Satinsky clamp or a tourniquet applied just below the origin of the innominate trunk. Two traction sutures of no. 00000 arterial silk were passed through the aortic wall and the aorta was incised longitudinally for a distance of 2 to 3.5 centimeters according to the size of the animal.

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* Preparation of this manuscript was unfortunately delayed for over a year due to the absence of one of the authors from this country.

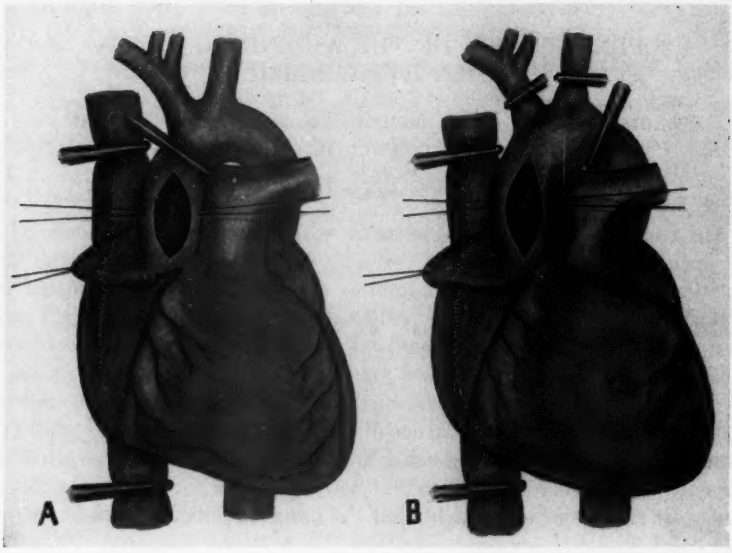

FIG. 1

In the second group, transverse anterior thoracotomy in the fourth interspaces with sternal transection was employed. After the pericardium had been incised, the venae cavae isolated, and the azygos ligated, the brachiocephalic trunk, the left subclavian, and the descending aorta distal to the arch were dissected free. Following procaine blockade of the superior vena caval atrial junction, the venae cavae were occluded and a minute later the descending aorta, the innominate trunk, and the left subclavian artery. The ascending aorta was then opened by means of a long longitudinal incision.

In both groups, blood was rapidly aspirated once the ascending aorta had been opened and respiration was arrested. A good view was then easily obtained of the aortic valve and the orifice of the left coronary artery. Instruments and a finger were then passed through the aortic valve into the left ventricle and the aortic cusps were intermittently grasped with a forceps. Approximately 1 minute after opening the aorta the field was usually quite dry, the blood contained in the lungs having been completely eliminated. In the animals in the second group with a longer aortotomy, an even better view of the valves was obtained than in the other group. After a period of time, the occlusion of the superior vena cava was released and intermittent inflation of the lungs was reinstituted. In approximately 1 minute blood began to flow from the left ventricle and filled the ascending aorta. Air was simultaneously expelled. At this moment the edges of the aortic incision were elevated by means of the traction sutures and a curved Potts ductus clamp was applied to close temporarily the incision. Normal cardiac rhythm was usually restored promptly although after release of the inferior vena caval clamp frequently the heart was gently compressed a few times and

very often 1 or 2 cubic centimeters of a solution of 1 to 20,000 epinephrine was injected into the right ventricle. The aortic incision was then repaired with a continuous over and over suture of no. 00000 arterial silk. In an occasional case a few interrupted sutures were required to stop small leaks.

OBSERVATIONS AND RESULTS

It was a striking observation that during the maneuvers described the heart rate slowed more than is usually the case when right or left ventriculotomies are carried out under hypothermia and superior vena caval right atrial procaine blockade.

In the first group of animals the temperature ranged from between 26.5 and 28 degrees Centigrade at the time of the aortotomy. The venae cavae were

TABLE I

Dogs with right thoracotomy and occlusion of the ascending aorta proximal to the innominate artery

Dog Number	Temperature of Dog in c.	Time of Caval Occlusion in minutes	Time of Open Aorta in minutes	Coronary Air Embolism	Ventricular Fibrillation	Final Result
1	27	11	10	No	No	Good—Sacrificed 15 days later
2	27.5	9.5	8	No	No	Good—Sacrificed 8 days later
3	27	10.5	9	No	Yes	Good—Sacrificed 11 days later
4	26.5	11	10	No	No	Good—Sacrificed 6 days later
5	27	11	9.5	No	No	Good—Sacrificed 15 days later
6	28	10	9.5	No	No	Good—Sacrificed 7 days later
7	27	13	12	No	No	Good—Sacrificed 21 days later
8	27.5	11	10	No	No	Good—Sacrificed 8 days later
9	26.5	15	14	Yes	No	Good—Sacrificed 9 days later
10	27.5	14	13	No	No	Good—Sacrificed 10 days later

TABLE II

Dogs with transversal thoracotomy and individual occlusion of the descending aorta, innominate and subclavian arteries

Dog Number	Temperature of Dog in c.	Time of Caval Occlusion in minutes	Time of Open Aorta in minutes	Coronary Air Embolism	Ventricular Fibrillation	Final Result
11	26.5	11	10.5	No	No	Good—Sacrificed 7 days later
12	27	14	12	No	No	Good—Sacrificed 11 days later
13	26	11.5	10.5	No	No	Good—Sacrificed 9 days later
14	27	12	11	No	No	Good—Sacrificed 8 days later
15	27.5	11.5	10.5	No	No	Good—Sacrificed 12 days later
16	27	13	12	Yes	Yes	Good—Sacrificed 20 days later
17	27	12	11	No	No	Good—Sacrificed 7 days later
18	28	10.5	9	No	No	Dead—Hemothorax
19	25	12	13	No	No	Good—Sacrificed 8 days later
20	26.5	11	10	No	No	Good—Sacrificed 5 days later

occluded for periods ranging from 9.5 to 15 minutes and the ascending aorta kept open for from 8 to 14 minutes. All of the animals recovered and were sacrificed in from 6 to 21 days. In a single instance ventricular fibrillation occurred without evidence of air embolism. This particular animal had been operated upon previously and had a stenosis of the proximal portion of the descending aorta created. It is possible that the increased resistance may have been implicated in the onset of fibrillation. The animal was easily defibrillated with massage, intracardiac epinephrine and electric shock. In a single instance, air embolism to the right coronary artery occurred, seemingly as a result of inadequate filling of the left ventricle and ascending aorta prior to closure of the aortotomy. Two small coronary branches were incised and air milked out before fibrillation developed.

In the second group of animals also the results were good. There was a single death on the day following operation due to massive hemothorax and it was impossible from postmortem examination to determine the site of the bleeding. The other animals recovered and were sacrificed in from 5 to 20 days. In a single animal, massive coronary air embolism occurred after resumption of circulation, apparently also as the result of inadequate filling of the left ventricle and aorta prior to closure of the aortotomy. Several small coronary branches were incised from which air escaped during massage following the administration of intracardiac epinephrine in order to improve the tone of the heart. Defibrillation was successfully accomplished with electric shock.

DISCUSSION

These experiments demonstrate that aortotomy with exposure of the aortic valves is feasible under moderate hypothermia with procaine blockade of the superior vena caval right atrial junction. It is our impression from these experiments that air embolism can be avoided provided cardiac contractions are good after resumption of circulation and the left ventricle and aorta are completely filled with blood prior to closure of the incision. In those instances in which vena caval occlusion was maintained for 11 or 12 minutes or more, the initial cardiac contractions were generally weak. Sometimes the heart had to be stimulated mechanically by percussing over the ventricles before left ventricular contractions were sufficiently forceful to fill this chamber and the ascending aorta and to eliminate all the air present. In most of the animals in which the vena caval occlusion was maintained for more than 10 minutes, brief periods of cardiac massage and the administration of a weak solution of epinephrine into the right ventricle were necessary in order to bring about strong cardiac activity once the operation had been completed. Coronary air embolism occurred in only 2 of the 20 animals. In both it was our impression that this mishap resulted from ineffectual ventricular contractions and failure of proper filling of the left ventricular chamber and the aorta. In both instances, the animals survived, and in only 1 did ventricular fibrillation occur.

Other investigators who have studied this problem of direct approach to the aortic valve are of the opinion that coronary air embolism constitutes the principal hazard. Adam and his associates[1] tried to prevent its occurrence either by

producing ventricular fibrillation or cardiac arrest. They abandoned these efforts in view of the fact that they had considerable difficulty in restoring normal cardiac activity. They therefore devised a technic by which the left ventricle was constantly perfused with saline solution during the period of vena caval occlusion and open aortotomy. Although this technic seemed to eliminate the possibility of air embolism their mortality was still 50 per cent. The same authors[2] subsequently devised a technic of retroperfusion of the coronary sinus with more encouraging results. Lewis and his associates[4] independently developed a technic which they employed in 19 dogs and 3 patients. During moderate hypothermia the venae cavae were occluded and a tape was tightened around the roots of the lungs. After the resumption of circulation the occlusion of the pulmonary roots was released and saline flushed through the left atrium by means of a metallic tube passed into the left ventricle through the aortotomy. This permitted them to eliminate all air trapped in the heart. The venae caval occlusion time in their 3 human patients ranged between 4 and 6 minutes. In discussing their paper, Swan[11] stated that he had operated upon 2 patients in a similar manner.

CONCLUSIONS

Our experiments impress us with the fact that if cardiac contractions are vigorous following vena caval release and prior to closure of the aortotomy, the ventricles and the ascending aorta become completely filled with blood and any trapped air is eliminated. If the venae caval occlusion time is not extended beyond 9 or 10 minutes in our experience the heart quickly resumes an effective beat. From these experiments, therefore, it would appear advisable not to occlude the inflow into the heart for a longer period of time.

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NEUROLOGIC LESIONS RESEMBLING AN ACUTE CONDITION WITHIN THE ABDOMEN

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Several strictly neurologic lesions producing abdominal pain may be easily confused with the "acute abdomen" caused by a diseased abdominal viscus. In view of the presence and the location of the pain, it is in many instances a very logical procedure to explore the abdomen. However, there are a number of safeguards in the clinical evaluation of abdominal pain which assist in differentiating between pain of strictly neurologic origin and pain referred from a diseased abdominal viscus.

The chief factors in differentiating neurologic lesions and abdominal lesions are the location and character of the abdominal pain and the associated symptoms. For example, in neurologic lesions such sensory manifestations as numbness, tingling and vermification may precede the pain. Pain then usually develops in the area in which the sensory changes occurred—that is, the area supplied by a specific nerve or nerves—and is confined to it. Pain of visceral origin may begin as diffuse pain and tenderness which become localized, but the area involved is not necessarily limited to the area of distribution of particular nerve roots and the pain is usually bilateral.

Since the location and limits of the area of pain are so important in this differentiation, the need to bear in mind the anatomy of the nerve root is obvious. As one may recall, spinal nerve roots are paired at the level of each dermatome. Each nerve is additionally divided into an anterior or motor nerve root and a posterior or sensory nerve root. These nerve roots then pass through the neural foramens of the spine and are distributed to the body, the sensory component to the sensory end organs and the motor fiber to the muscle end plates.

Sensation from a *diseased viscus* is received through sensory nerve fibers but is referred to a larger area of the body not necessarily related to a dermatome pattern or peripheral nerve root distribution.

But in contrast, the signs and symptoms of direct involvement of a spinal nerve root, are limited to the area of the body supplied by that nerve. Even when the sensory and motor symptoms are "spotty" and incomplete, indicating that the nerve is only partially involved, they will still be restricted to the area of the peripheral nerve supply of that nerve.

The pain of *herpes zoster* is an excellent example of pain limited to the dermatome distribution of specific nerve roots. An attack of herpes zoster is usually ushered in by a sudden attack of severe root pain which appears without warning. In the area involved, there is intense hyperesthesia, burning and lancinating pain. If the pain is distributed over the abdomen, it may easily be confused with

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acute abdominal pain of visceral origin unless its confinement to the area of distribution of an individual nerve root is noted. When the diagnosis is doubtful, blocking the involved posterior nerve root or roots with local anesthetic directly or by epidural injection may temporarily abolish the superficial pain. If deep abdominal pain and tenderness are not abolished, a diseased viscus may be indicated.

The development of a papular eruption of the skin in the area affected by pain also helps to establish the case as herpes zoster.

Myelitis, a primary inflammatory lesion of the spinal cord, may develop alone or in association with many infectious diseases. Pain in this disease is usually present only at the very onset, but the involvement of the spinal cord is usually rapid, and the period of pain before sensory and motor paralysis below the level of the lesion is, therefore, very short. It is this rapidly developing pattern of symptoms and signs which identifies the etiology.

Poliomyelitis often begins with an upper respiratory infection. When fever develops, pain may appear just prior to motor paralysis. Pain across the abdomen can be easily confused with the pain of an acute condition within the abdomen. However, the infectious onset followed by paralysis helps to differentiate it. The finding of white cells in the spinal fluid also assists in the differentiation.

Polyneuritis is a general term used to describe a number of conditions affecting peripheral nerves. Ethyl alcohol and other organic chemical poisonings, heavy metal poisonings, virus and other infectious involvement, diabetes, pernicious anemia, multiple sclerosis, certain vitamin deficiencies, porphyrinuria and leprosy involve peripheral nerves directly as well as other parts of the nervous system and produce symptoms localized to the distribution of those nerves. In general, the nerves involved in these conditions are inflamed, swollen, tender and painful. Such sensory disturbances as numbness, tingling, pins-and-needles and formication appear before the pain and weakness. The involvement in polyneuritis is chiefly in the extremities, but when it is limited to the abdominal wall and abdominal musculature, it may be confused with an acute abdomen. The history of prodromal symptoms of numbness and tingling followed by pain and paralysis helps to establish the cause of the pain as polyneuritis.

Spinal arthritis notoriously produces radicular nerve root pain. As the bone proliferation fills the neural foramen of the spine, the nerve roots become irritated and pain results. This radicular pain is slow in onset; it is capable of being altered by changes in position of the back. When it is referred to the abdominal wall, it may sometimes be confused with the pain of an acute abdomen. A local anesthetic block of the nerve roots will usually temporarily abolish it and assist in differentiating the diagnosis.

Spinal fractures frequently involve the spinal nerve roots as they pass through the neural foramens. When the fracture extends through the laminal arch, it may also extend into the foramen. Hemorrhage and swelling may then develop

in and around the nerve root; spicules of bone may penetrate or lacerate it; and the fractured or dislocated spine may compress or stretch it.

The resulting symptoms are various. If they are from irritation, pain, sensitiveness, numbness and tingling may appear. If they are destructive, anesthesia and abdominal wall paralysis may result.

When pain and hyperesthesia are present, abdominal wall rigidity and tenderness may be present.

But unless a viscus has been damaged, there is usually no deep abdominal tenderness and sensory changes are limited to the distribution of the nerve root or roots involved. When uncertainty exists as to the cause of the abdominal pain, tenderness and rigidity, exploratory laparotomy may be imperative to establish the correct diagnosis.

Postoperative abdominal scars at times involve the peripheral nerves that cross the abdomen. Pain then develops in the scar and in that portion of the abdominal wall which the nerves supply. This pain and tenderness may be difficult to distinguish from that of an acute abdomen. The injection of local anesthetic into the scar, however, will usually arrest the pain and establish its neural origin.

Intervertebral disk rupture may occur in the dorsal spine although it is infrequent. The pain resulting may be in the back, the chest or along the abdominal wall. As the disk becomes distended, the pain is primarily in the back. When the disk ruptures and compresses one or more nerve roots, the pain spreads to the chest or abdominal wall in the area of the distribution of the nerve involved. A large disk may compress the nerve roots bilaterally and may additionally compress the spinal cord causing pain on both sides of the abdomen and weakness and paralysis of the legs. Abdominal pain from compression of a nerve root by a disk usually develops slowly; it can be altered by changes in position of the back and may be temporarily abolished by local anesthetic blocking.

The pain of benign *spinal cord tumor* is somewhat similar to that of a disk. However, it as a rule begins as a dull backache followed by occasional shooting pains in the area of the distribution of the nerves involved. These intermittent shooting pains in the extremities, the chest or the abdomen are sudden and sharp; they cease as abruptly as they appear but return with surprising severity. Gradually the severity and frequency increase until the pain becomes constant; numbness and weakness appear at this level and below the level of pain. If the pain is in the abdomen, the abdominal wall becomes numb and paralysis of the legs develops.

The initial pain of spinal cord tumor is usually a true radicular pain, being unilateral and involving a specific nerve root. The pain is sharp, cutting and lightning like and of such severity that it wakes a patient at night. Often the pain is relieved by a particular position of the back or by the activity of getting up and walking.

Metastatic spine and spinal cord tumors may involve the spine, spinal nerve roots or the spinal cord. The symptom pattern may closely resemble that of

primary benign tumors and the diagnosis and surgical removal are similar. The problem is chiefly one of determining whether the lesion is malignant or benign.

The conditions discussed involve the spinal cord and nerve roots specifically and as a result the symptom pattern is clear. Other conditions involving the spine and spinal cord in a more diffuse manner cannot be identified so clearly by their neurologic symptom pattern.

In *tabetic crises* the pain is lightning like and very intense. It is usually felt in the stomach, intestines, rectum, bladder, ureters and kidneys. It may not always follow a nerve root pattern. However, its characteristics, the spinal fluid findings and the associated symptoms establish it as pain of tabetic origin.

Spinal cord concussion may occur following contusion of the back. This contusion may be in the nature of a direct blow received in falling flat on the back, being struck across the back with a plank, or being hit on the back by a flying object such as a rock, brick or shell fragment. Following such an injury, the legs at times may be weak, numb and partially paralyzed; at other times, the lower extremities may not be affected. But in either case, the abdomen may be found to be rigid and painful, with extreme hyperesthesia over it and with spasm of the abdominal musculature. As sensation returns, hyperesthesia, muscle rigidity and pain in the abdomen may increase for a time. It is sometimes impossible to establish a clear distinction between the pain of an acute abdomen and the pain and muscle spasm of a spinal cord concussion. A spinal cord concussion certainly should be suspected following an injury if there is sensory and motor functional loss in the lower extremities.

Abdominal pain of a *psychoneurotic* origin is probably the most difficult to diagnose. It requires prolonged study and careful evaluation. It may resemble any distribution pattern, any character, and be related to any event in the patient's life. Usually the symptoms of acute infection with fever are lacking. Often the pattern of symptoms varies from time to time in such a way as to initiate suspicion of its psychoneurotic origin. This suspicion may be strengthened by the patient's erratic mental pattern. In spite of all the precautions, at times abdominal pain from psychoneurosis and abdominal pain from visceral disease cannot be differentiated.

SUMMARY

In summary, the character of the abdominal symptoms in visceral disease differs from that in nerve root involvement in a number of ways.

With *visceral disease*, the symptoms, chiefly pain, tenderness, rigidity and muscle spasm may be widespread throughout the abdomen or be localized to a small area. In most cases, the first symptom is general abdominal involvement which is followed shortly by a localized sensory and motor involvement. But even in the final stage, the symptoms do not follow the pattern of peripheral nerve distribution. For example, symptoms in an abdominal quadrant from visceral disease are not localized to one, two or several nerve roots specifically and both sides of the abdomen may be involved.

On the contrary, abdominal symptoms of *neurologic origin* tend strictly to follow the dermatome and peripheral nerve patterns. Often partial or complete paralysis accompanies the pain, tenderness, numbness, tingling and other sensory symptoms. The paralysis, which may not be apparent at first, becomes evident as sensory changes become more prominent.

Finally, differentiation of abdominal symptoms from a diseased viscus or a diseased nerve depends chiefly on the character and distribution of the symptoms. An understanding of the anatomy of the nerve root assists in making this differentiation.

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ROTARY LAWN MOWER INJURIES

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Even in this modern age of machinery and the hazards associated with it, attention is attracted to the startling increase in number and the seriousness of injuries inflicted by rotary power lawn mowers. Because of the ease of handling and efficiency of performance, the rotary machines have become tremendously popular during the past few years; and manufacturers estimate that 2,000,000 of these mowers will be sold in the United States in 1957. They are used by people of all ages with little regard to the terrific destructive potential they possess.

In the private hospital with which I am associated, approximately 3,300 emergencies have been treated each year for the last three years. The following table shows the dramatic rise in lawn mower injuries during the same period:

Year	Total No. of Lawn Mower Injuries	Number of Rotary Lawn Mower Injuries
1953	2	0
1954	11	9
1955	19	18
1956	24	23
Total	56	50

There has been very little written in the Medical literature about these cases, but Iovine[1] reported in 1954 that the blades at their high rate of revolutions per minute are capable of great cutting power and act as dangerous flying missiles when broken. In 1955 Kurth, Drever, and Baran[2] reported a case of decortication of scalp and skull by a rotary mower. At the recent meeting of the Southern Medical Association in Washington, D. C., Dr. Miller[3] presented a series of power mower injuries treated in Gastonia, N. C., limiting his discussion to flying missile type injuries.

In spite of the scarcity of reported cases, inquiry at several other hospitals reveals that the rise in this type of trauma has not been confined to our emergency treatment. The patients treated in our hospital represent only one-fifth of the emergencies in the Richmond, Virginia area, which has a population of slightly less than 400,000, and the total number of injuries in the United States must be staggering. A rough estimate based on the above figures would put the number of accidents in the United States caused by rotary power lawn mowers at 50,000 for 1956.

From the Johnston-Willis Hospital, Richmond, Virginia.
This paper was entered in the Scientific Award Essay Contest of the Southeastern Surgical Congress, 1957.

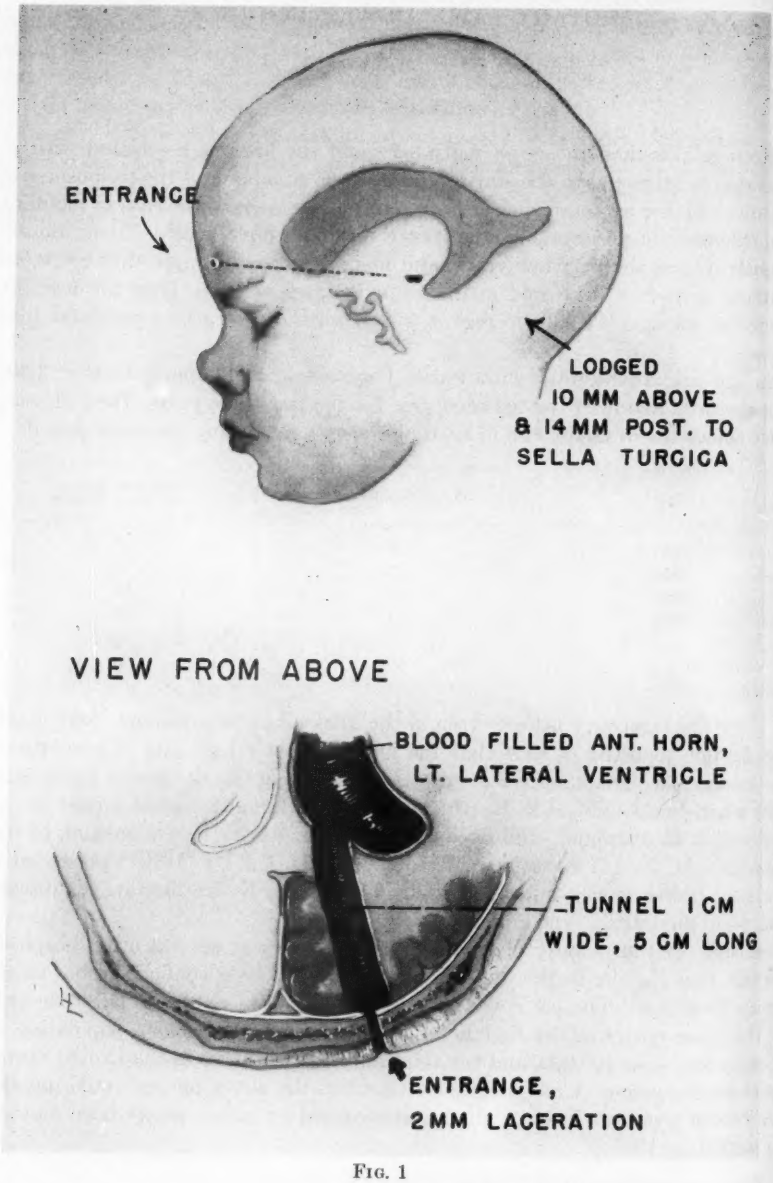
ENTRANCE
LODGED
10 MM ABOVE
& 14 MM POST. TO
SELLA TURCICA
VIEW FROM ABOVE
BLOOD FILLED ANT. HORN,
LT. LATERAL VENTRICLE
TUNNEL 1 CM
WIDE, 5 CM LONG
ENTRANCE,
2MM LACERATION

FIG. 1

The patients who had rotary lawn mower injuries treated in our emergency room have been analyzed and include people of both sexes with ages varying from 3 to 75 years and from all walks of life. The injuries have been divided into four general types and 7 cases are presented to illustrate the extent and variety of trauma that can be associated with these machines.

Six of the patients had injuries caused by flying particles of blades broken off by striking some hard object. Case 1 is not one of our series but is presented because of the unusual nature of the injury and because it so graphically demonstrates this hazard.

The largest group comprising 22 patients consists of persons who were injured by walking into the mower or by pulling the machine back over their feet.

CASE REPORTS

Case 1. A 14 month old white female was in her mother's arms watching her father mow the lawn when the blade hit a hard object. The child cried out, lost consciousness, and was rushed to the hospital of the Medical College of Virginia. Examination revealed a 2 mm. laceration of the left forehead surrounded by a small hematoma. The child would not respond to painful stimulus. There was extension rigidity of the right extremities.

A roentgenogram of the skull revealed a 2 by 10 mm. foreign body lodged 10 mm. above and 14 mm. posterior to the sella turcica.

An operation was performed immediately and upon exposing the skull a compound fracture of the left frontal area was revealed. A 4 by 4 cm. section of bone was excised and a tunnel 1 cm. in diameter was found extending 4–5 cm. through the left frontal lobe into the left lateral ventricle (fig. 1). About 15 cc. of clotted blood was expelled spontaneously and hemostasis was obtained by cauterization. The foreign body was considered too deeply imbedded to remove and the wound was closed.

The child did well following operation, regained consciousness and use of her right arm and leg, but did have Jacksonian convulsions on her fourth postoperative day.

She was discharged on phenobarbital and dilantin to be followed as an out-patient. No further convulsions have been reported during the 3 months that have elapsed, but some spasticity of her right side is present.

Note: This case is reported through the courtesy of Dr. Jon Meredith, Medical College of Virginia.

Case 2. A 12 year old white male slipped while mowing the lawn, pulling the rotary mower back on his foot. The blade cut through his shoe, amputating the first and second right toes and a portion of the medial side of the right foot (fig. 2).

The foot was cleaned and debrided and the middle toe which was badly lacerated was sutured although amputation was considered. After the wound began granulating, split thickness skin grafts were applied with satisfactory results. He now walks and runs on the foot with no marked difficulty in maintaining balance.

Case 3. A 33 year old white female walked too close to her mower while picking up sticks and amputated her third left toe. She also suffered deep lacerations of the fourth and fifth left toes (fig. 3) which were sutured after reconstruction of the stump.

Case 4. A 21 year old white man pulled his rotary mower back on his foot and amputated his right great toe and portions of the second, third and fourth right toes. Subsequently all four stumps required revision. The injury has resulted in a limp.

Case 5. A 33 year old white man attempted to remove weeds from his rotary mower without stopping the motor thereby incurring a traumatic amputation of the tips of his left index and middle fingers (fig. 5). The stumps required extensive debridement.

Case 6. A 53 year old white salesman while attempting to clean his rotary mower caught the tip of his third right finger in the blades, resulting in an unusual "splitting" injury (fig. 6). The flaps were sutured together after careful debridement with satisfactory healing.

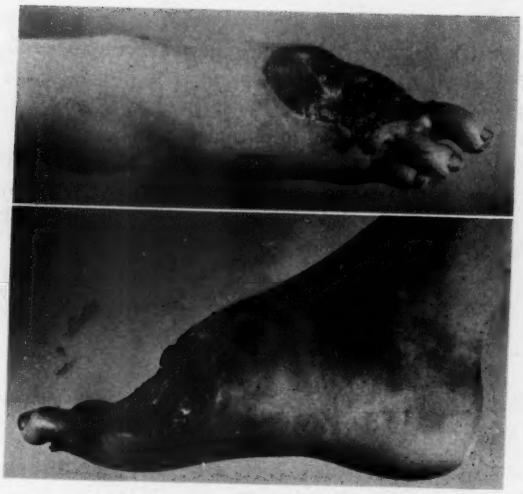

FIG. 2

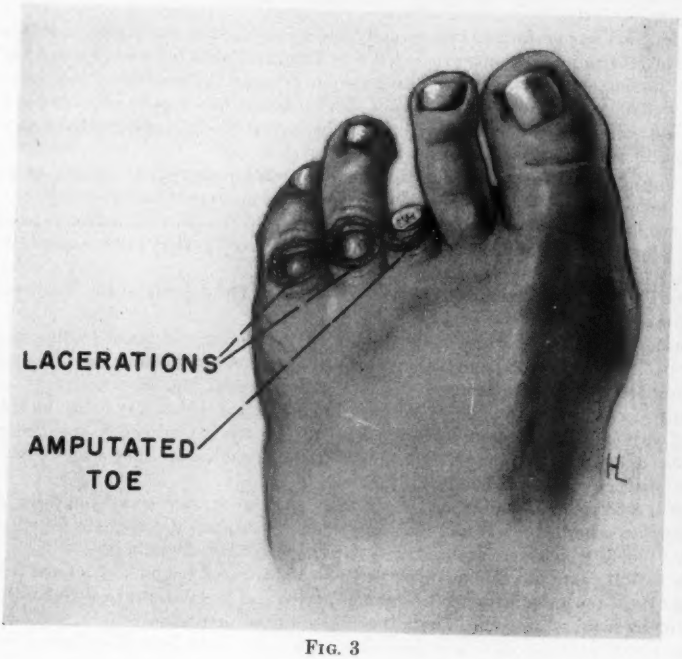

FIG. 3

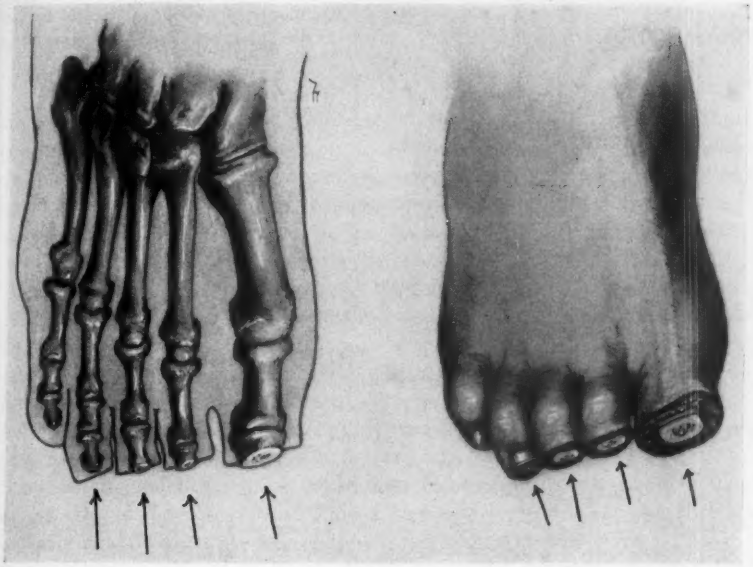

FIG. 4

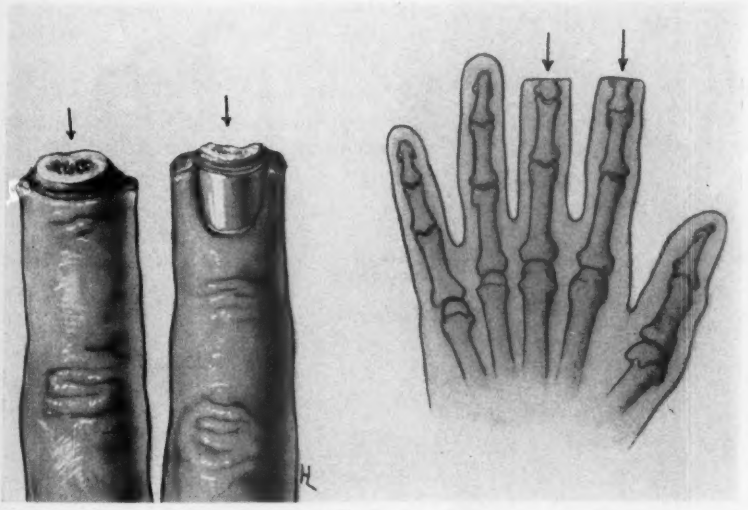

FIG. 5

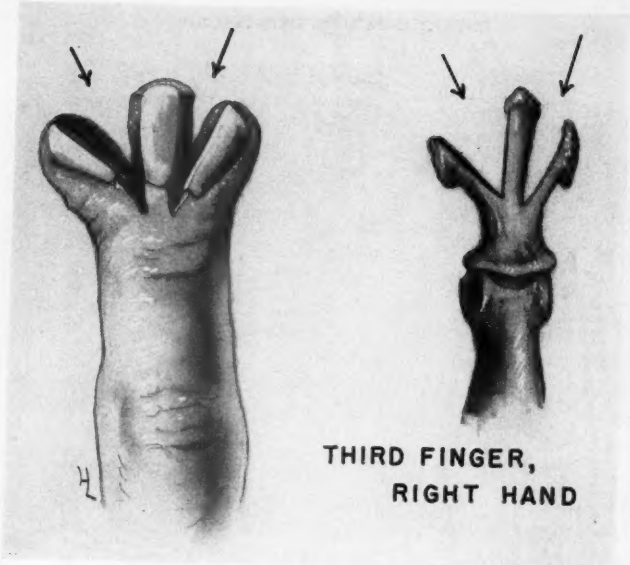

FIG. 6

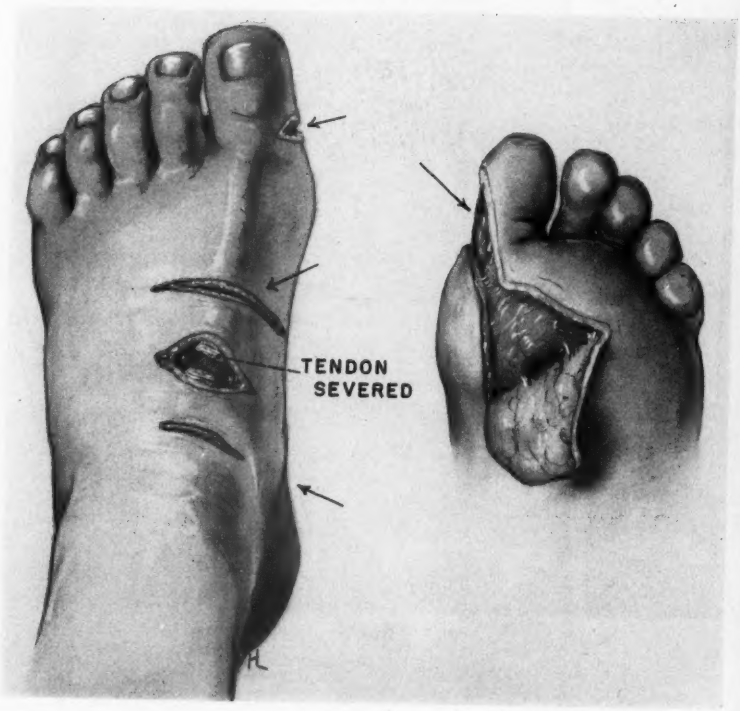

FIG. 7

Case 7. A 4 year old white girl, playing in the yard while her father was mowing, attempted to leap over the rotary machine. She slipped and fell in front of the mower incurring lacerations of the dorsum and sole of her left foot (fig. 7). No permanent defect resulted.

DISCUSSION

In an attempt to find some cause for the rise in rotary lawn mower injuries, questionnaires were sent to each of 50 patients so injured. They were asked to give the trade name of their mower, to describe the accident in detail, and to suggest any changes they thought might prevent trauma in the future.

Most of the patients replied to the questionnaire. No particular make of mower appears more dangerous than the other.

All of the hand injuries and some of the foot injuries were believed to be due to carelessness. Carelessness, however, is part of human nature, particularly with such a common tool as the lawn mower. Although education of the public would be a step in the right direction, the burden of decreasing the number of injuries lies with the manufacturers. This would appear particularly true in cases of flying missiles and feet slipping under the mower. This type accident should not be blamed on the operator's neglect.

Some of the machines have inadequate safety guards which allow feet to slide into the blades too readily. This is particularly true in dry weather when the blades are raised to prevent chopping the grass too close.

Some mowers are now equipped with clutches to disengage the blades with the motor running. This seems to be an excellent accessory. A machine with the clutch on the handle requiring constant pressure to engage the blade would certainly be of benefit to those who persist in cleaning the mower without cutting it off.

The automobile industry has become "safety conscious". Wringer injuries are now a rarity because of safety features that have been added. There is no reason why rotary lawn mowers should continue to reap such a bountiful harvest of fingers and toes.

SUMMARY

The incidence, seriousness and variety of rotary lawn mower injuries are discussed.

Suggestions are made from the viewpoint of desirable additional safety features.

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MANAGEMENT OF RECURRENT THYROID NODULES

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The true frequency of recurrent goiter is hard to determine but is undoubtedly greater than realized by those who believe that they take care of routine thyroid problems with great skill, trivial morbidity, and no mortality. We were surprised to find, in a recent review of 1228 consecutive thyroid operations, that 1 in every 14 was performed for a recurrence.* [2]

Patients with recurrent thyroid nodules seek advice and treatment because of cosmetic or pressure symptoms, because of thyrotoxicosis, or because they or the referring physician fear that the recurrent lump may be cancer. In the past a fair number of these patients have been subjected to needless surgery to exclude cancer. The purpose of this discussion is to present a rational plan for management of recurrent thyroid lumps.

Our present knowledge of thyroid patho-physiology, gained largely through use of radioactive iodine, clearly indicates that surgical removal of goiter is not *definitive* treatment except in so far as it may relieve symptoms or remove a primary neoplasm.[4, 10, 13] Although symptoms of toxic goiter can be relieved by thyroidectomy, it is well known that intense hyperplasia continues in the remnants,[1] and recent tracer studies have re-emphasized that radical resection is essential to avoid recurrence or persistence of symptoms.[12] In much the same way nontoxic nodular goiter, which results from prolonged pituitary stimulation of a flagging thyroid gland, may recur promptly because the basic pathologic physiology has not been corrected by removal of a lobe or enucleation of a nodule.[13] In fact, one should expect that removal of functioning thyroid tissue may result in even greater pituitary stimulation of the remnant.[4, 6, 7] These facts are borne out by an analysis of the 90 reoperations found in our survey.

Thirty-six patients were originally operated upon for toxic symptoms, and 94 per cent recurred because the primary resection was too conservative or because of hyperplasia in superior poles and pyramidal lobes which were left intact. Because of the latter two faulty practices, recurrent nodules developed in these locations in one half of all the patients who had had a primary bilateral subtotal resection.

Fifty-four of the cases were originally nontoxic and 22 recurred in spite of a bilateral resection; 12 recurred because of enucleation of nodules or partial lobectomies; and 22 recurred in lobes which were grossly normal at the first operation.

The patient with a recurrent thyroid lump deserves the most careful evaluation rather than a quick trip to the operating room. First, the tissue sections from

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* Toxic goiters which persisted or recurred within 1 year were excluded. Primary malignant tumors which recurred were not included.

the primary operation should always be reviewed if available.[5, 9, 14] Although malignancy must be excluded, the possibility of a primary diffuse toxic goiter or a nontoxic nodular goiter recurring as a malignant neoplasm is apparently rather remote. Three of the 90 recurrent goiters in our survey were malignant, but careful review of the original reports and tissue sections showed that all 3 were suspected of being cancer. These cases presented fetal adenomas with papillary formation or trabecular adenomas with cellular atypicalities but no capsule or blood vessel invasion. We are convinced that these malignant cases represent a change in pathologic interpretation rather than a change in the pathology of the gland.[14] No carcinoma was found in the remaining patients, where the primary disease had been benign without reservation. For this reason we believe that reoperation is not *mandatory* to exclude cancer in a recurrent goiter unless the original lesion was suspicious or unless the tissue sections are not available for review. Large, hard, or rapidly enlarging masses should obviously be removed surgically, but we believe that smaller symptomless masses can be safely given a trial of nonoperative treatment.

In order to select the proper nonoperative treatment, one should re-evaluate the patient's metabolic status by laboratory as well as clinical tests. If hyperthyroidism exists, we think that treatment with antithyroid drugs or KI or radioactive iodine should be used unless the recurrent goiter is large or producing mechanical symptoms. The choice of nonoperative treatment is based upon the fact that the major complication rate in our 90 secondary operations was found to be 25 per cent, and four fifths of the recurrent laryngeal nerve palsies occurred in the patients who had toxic cases (which, of course, were more radically resected). In most patients nonoperative treatment is not only free of complications but entirely effective.

Should reoperation be performed, great care must be taken to avoid recurrent laryngeal nerve trauma,[3, 8, 11] and preserve remaining parathyroids. Parenthetically, it may be well to recall that patients with unilateral cord palsies from a first operation may regain a remarkably normal voice. For this reason we routinely examine the vocal cords before all reoperations, because even temporary paresis from operative trauma on the normal side may result in complete respiratory obstruction. Since this may not be recognized until an endotracheal tube is removed, people with old, unilateral cord palsies should have a prophylactic tracheotomy or should be warned that one may be necessary.

Finally, we come to the management of those recurrent goiters which are associated with normal or subnormal metabolism. These cases made up three fourths of our series. Some of the smaller nodules are characteristically found in pyramidal lobes or superior poles. If one realizes that such remnants have been left with *great* frequency in the past, there is no reason to suspect that they are metastatic nodules. They will often respond very well to thyroid hormone,[7] but they will usually enlarge if the patient is given iodine or propylthiouracil. On the other hand, because they grow slowly and produce symptoms gradually, some of these recurrent nontoxic goiters may become very large and produce acute pressure symptoms. Such large masses should be promptly excised. In

FIGS. 1 AND 2. This 43 year old para V had total right lobectomy 16 years ago for nodular goiter. No interval treatment. Sought treatment for cosmetic and pressure symptoms. Surgical specimen weighed 230 Gms. Note level of primary and secondary scars on fifth postoperative day. This recurrence might have been prevented by supplementary thyroid.

fact, so many of our patients who had nontoxic recurrent cases required surgery because of apparently new nodules or enlarging remnants in superficial locations, that we are convinced that nontoxic nodular goiters should be treated by a fairly radical primary subtotal resection followed by a permanent maintenance supplement of thyroid hormone.

In summary, we believe that recurrent thyroid nodules have a very small risk of malignancy unless the primary goiter was a neoplasm such as a fetal or trabecular adenoma. Recurrent toxic goiter should be treated by nonoperative measures unless pressure or cosmetic symptoms make reoperation necessary. The technic of reoperation must be meticulous to avoid serious complications. Many nontoxic recurrent goiters can be improved by giving thyroid extract, but reoperation will be necessary for those which have been allowed to reach large size following conservative primary surgery.

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UROLOGY IN THE COAL FIELDS

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The title of this paper "Urology In The Coal Fields" may create the impression of unusual types of urology limited to the coal mining areas, therefore I desire to state that our patients are the same as you might find anywhere in this land of ours. I also wish to state that, although my particular locality has been widely publicized in a very recent article in a popular magazine, none of the patients whose cases I will review have been treated with black cat's blood or an application of copper wire, or sardine oil, although in some I probably would have welcomed the use of most any of the voodoo charms that would have been handy to bring a safe and happy conclusion to these cases.

In actuality, the practice of urology in the coal field area has been greatly complicated by the necessity of having to deal with a rather widespread, and almost endemic type of lung disease which is not often found except in specialized industries elsewhere in this country. This pulmonary disease which we see too often in the coal field areas can be classified in two general groups.

1. Silicosis.

2. Emphysema and associated complications with decrease of pulmonary capacity of varying degree.

In the first, silicosis, the pathologic factor underlying this complication is a deposit of silica of minute size in a form of dust which is inhaled by these men involved in the coal mining industry as they drill through rock deep underground. The disease as defined by the Compensation Commission of the Silicosis Board is classified as Stage 1, 2, and 3. In stage 1, there is radiologic evidence of marked increased bronchovascular markings, and very small beading noted throughout the lung fields, or it may be limited to one lung field. In stage 2 there is radiologic evidence plus pulmonary disability where the beading is more pronounced, and more diffuse throughout all the lung fields. In stage 3 there is radiologic evidence plus complete pulmonary disability, where there is a conglomeration of the nodulation in the intralobular spaces with coalescing of the nodules, and in some cases where tuberculosis has complicated the picture, cavitation with fluid levels are noted. In emphysema, the problem is a deposition of the carbon particles in a fine dust form, which apparently sets up a reaction in the small lobules of the lung and in the interstitial tissue surrounding the small lobules causing increased deposition of fibrous material with resulting fibrosis and lack of expansible ability of the lungs. This, in turn, creates a secondary difficulty, or accompanying difficulty of emphysema with marked respiratory distress. Most of these men have barrel shaped chests with a greater antero-posterior diameter than the lateral diameter. As can well be seen by the foregoing descrip-

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tion of the pulmonary diseases involved, these patients have a decreased vital capacity in relation to their oxygen intake. With a corresponding degree of dyspnea, depending upon the severity of their individual pathologic picture, it is not too uncommon to see these men reduced to the state of bed-fastness with 24 hour oxygen therapy being necessary to sustain life.

Now it can be seen easily that these men, some of whom have worked as many as 50 to 55 years in the coal fields, beginning at an extremely early age, are beset not only with their pulmonary pathology, but also fall ill to pathologic conditions involving the genitourinary system of which I will speak specifically today. It must be borne in mind that the patients mentioned are also victims of moderate to severe crippling pulmonary pathology.

We shall endeavor to review the years 1953, 1954, 1955, and 1956, as to the number, the average age group, and type of operation performed for this series. In 1953, at the Raleigh General Hospital in Beckley, West Virginia, 129 cystoscopic examinations were performed on patients between the ages of 20 and 65. I might explain that some of the patients who were admitted to the hospital had previously had cystoscopic examinations performed in my office and are not included in this series. In 1953 we performed 39 transurethral resections of the prostate on patients between the ages of 55 and 70; also 17 prostatectomies, suprapubic, perineal, or retrapubic on patients between the ages of 60 and 70. We had 5 patients in 1953 in whom orchidectomy was performed either bilateral or singular, between the ages of 60 and 75. There were also in 1953 2 patients who had nephrolithotomies between the ages of 50 and 64. In 1953 also there were 2 nephrectomies on patients between the ages of 51 and 68. In 1954 there were 105 cystoscopic examinations performed on patients between the ages of 35 and 55. In 1954 there were 45 transurethral resections performed on patients between the ages of 55 and 70. There were 6 prostatectomies in 1954 of the various types performed on patients between the ages of 60 and 75. In 1954 orchidectomy was again performed on 10 patients between the ages of 40 and 70, and in 1954, 2 cases of nephrolithotomy on patients between the ages of 31 and 81. Also in 1954, 5 nephrectomies were performed on patients between the ages of 46 and 70. In 1955 there were 88 cystoscopic examinations performed on patients between the ages of 55 and 75. In 1955 there were 55 transurethral resections on patients between the ages of 55 to 75. One prostatectomy on a patient 65 years of age, and 11 orchidectomies were performed in 1955 on patients between the ages of 55 and 75. In 1955 there were 3 cases of nephrolithotomy on patients between the ages of 28 and 49. There were 5 cases of nephrectomy on patients aged 27 to 75. In 1956 there were 51 cystoscopic examinations performed on patients between the ages of 55 and 75. In 1956 there were 27 transurethral resections performed on patients between the ages of 55 and 75. There were 10 prostatectomies in 1956 on patients between the ages of 45 and 79. There were 6 cases of orchidectomy in 1956 on patients between the ages of 60 and 70 plus. There were 3 cases of nephrolithotomy on patients between the ages of 30 and 61. There were 5 cases of nephrectomy on patients between the ages of 30 and 61.

These statistics are only given in an endeavor to show that, although the patient suffers with a crippling pulmonary pathology, he can be treated for other existing pathologies that may occur. In 1953 there were 8 deaths of patients in the urologic service, in 1954 there were 7 deaths; in 1955 10; and in 1956 4 deaths. In 1953 which is a typical year, one death was due to cerebral hemorrhage, prior to surgery. One death was due to primary carcinoma of the ureter with generalized metastasis, and one death was due to chronic nephritis with uremia. One death was due to renal failure of a solitary kidney. One death was a postpelvic extirpation operation, death being due to ascending pyelonephritis and uremia. This was in a woman who had been sent by the United Mine Workers Health and Welfare Fund to New York, and a cutaneous ureterostomy had been performed. Another death due to carcinomatosis, generalized from an undiagnosed carcinoma of the prostate. This patient was seen for the first time in the terminal stage. There was one death due to pulmonary embolus, secondary to thrombophlebitis in the left lower leg. This patient died 72 hours after surgery. I believe that this was the only surgical death that we had in this series in 1953. A 78 year old Negro man died of a cerebral hemorrhage 9 days following surgery. He had been discharged from the hospital in the morning prior to his death.

It might be interesting to those of you who have never encountered this severity of pulmonary pathology to learn how we go about determining whether or not these patients are fair surgical risks in relation to their urologic pathology.

In the preoperative phase, I shall try to list our routine procedure and then enlarge briefly on each topic.

1. History and physical examination.
2. Admission chest roentgenogram.
3. Electrocardiographic studies.
4. Laboratory studies.
5. Consultation—medical and anesthesia.

Our history and physical examination is usually completed in the office prior to admission. It includes a careful review of symptoms, and in particular the length of time the patient has worked in the coal mines, and what type of work, and whether or not he has had treatment for any pulmonary pathology.

Admission chest roentgenogram is taken as a routine. If the radiologist, Dr. J. R. Lewin, deems it necessary, further films are secured and the extent of pulmonary pathology is determined.

Electrocardiographic studies are secured on all patients suffering from any pulmonary pathology, because of the possibility of cor pulmonale, and right cardiac ventricular hypertrophy, which is a result of their lung disease.

Laboratory studies include a complete blood count and urinalysis with bacteriologic culture and sensitivity studies; non-protein nitrogen and urea nitrogen, serology, bleeding and clotting time, phenolsulfophthalein test, indigo carmine, and electrolyte studies.

Consultation is secured from one of the internists, and a complete review of the patient is then performed, and in particular his status as a surgical risk is

determined. At this time our anesthesiologist is consulted, and a determination of the most suitable anesthesia to be given is discussed and decided upon.

The anesthesia generally used with the least embarrassment to the cardiac and pulmonary processes has been spinal anesthesia. In our prostatectomy cases the anesthesiologist, Dr. Wade H. Rardin, has been most successful in limiting the height of his anesthesia just to the point necessary to relieve the patient of pain throughout the surgical period. He is also in consultation for a period of 72 hours postoperative for any pulmonary complications which may arise as a result of the anesthesia. Our internist is also in consultation for any possible cardiac complications.

The size of the prostate gland does not always determine the type of procedure performed. The main factor that we consider in our consultation discussions is the method of surgery which will give the patient the greatest relief of his urologic distress with the least embarrassment to his pulmonary and cardiac pathology. Therefore, as you have noted in the prior statistics more transurethral resections of the prostate have been performed than by the suprapubic, perineal, or retropubic method. In our hands transurethral resection has resulted in the greatest degree of improvement in the patient without complications or fatal conclusion in these already crippled individuals. In the other cases which we mentioned, such as nephrectomy, nephrolithotomy, orchiectomy, etc., a consideration of the safe length of time of the operation was stressed in consultation with the internist, radiologist, and anesthesiologist.

In the postoperative phase I shall list in degree of importance to me the steps we follow and briefly discuss each:

1. Nursing care.
2. Fluid balance and diet.
3. Ambulation.
4. Antibiotics.

Nursing care in the postoperative phase, I believe, is the most important factor in the recovery of these patients. All of our nurses are trained in special classes in after care of urologic surgery patients. In this fact we are most fortunate as they are especially careful in the irrigations of the prostatectomy patients and any adverse symptoms are promptly reported, such as, excessive bleeding, respiratory distress, or cardiac irregularities.

In all of these patients we have found that if no nausea develops postoperatively that they recover much faster if normal diet and fluids are started within 12 hours. We have also found that a mild laxative on the second postoperative day is all that is necessary to resume normal bowel habit. Purgatives or enemas are not used on prostatectomy patients, especially in those patients who are suffering from a crippling pulmonary disease.

Early ambulation has been used on all patients who are able to be out of bed, in this we mean those patients who were not restricted to bed by dyspnea and constant oxygen therapy. Even in these patients we have encouraged sitting up, moving their legs, and other bed exercises that would increase their circulation without causing undue strain on their respiratory mechanism.

Antibiotic therapy is restricted in use to the specific one as determined by culture and sensitivity tests. We usually repeat cultures every 4 to 5 days, and if negative, all antibiotics are stopped. It has been interesting to note that in the patients with severe emphysema and bronchiectasis, their productive sputum has not only lessened in amount, but cleared considerably while undergoing antibiotic therapy for their urologic disease.

SUMMARY

In summary I would like to restate that patients with severe crippling pulmonary pathology can be safely treated for their genitourinary diseases. I believe that the successful handling of these difficult cases can be attributed to whole-hearted assistance rendered by the internist, radiologist, and anesthesiologist.

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SPONTANEOUS RUPTURE OF PSEUDOCYSTS OF THE PANCREAS

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Although many articles have been written on the diagnosis and treatment of pseudocysts of the pancreas, only a few authors discuss in detail the catastrophic complication of rupture of these cysts. It is the purpose of this paper to review surgical thinking on this subject, and to report 2 of our own cases.

Robson and Moynihan[5] cite a case of Dixon's reported in 1884 in which the patient died following the free peritoneal rupture of a pancreatic cyst. They also described a case of their own in which a traumatic cyst of the pancreas perforated with a fatal outcome. Another of the earliest cases of rupture is reported by Swartz as noted by Opie.[3] Koucky, Beck and Todd[1] reported 6 cases in which rupture into the peritoneal cavity occurred and another with perforation into the duodenum. Pinkham,[4] reporting 10 cases of pseudocysts, described one patient in whom intraperitoneal rupture occurred shortly before elective surgery was performed to drain the cyst. From Australia, Rose[6] described another case. A mortality of 75 per cent is recorded by Meyer[2] in 4 patients who experienced this catastrophe. Stephenson[7] witnessed the rupture of a pseudocyst in a patient as the surgeon demonstrated it by palpation just prior to elective drainage of the cyst.

REPORT OF CASES

Case 1: C.R.C. This 33 year old automobile parts salesman was admitted to the Atlanta Veterans Administration Hospital in April 1954 complaining of a painful "knot" in the upper abdomen. He first became sick in February 1952 when he developed jaundice which cleared in about 2 weeks. About this time he began supplementing his diet with a pint of whiskey daily for the next 2 years. In January 1953 he again developed jaundice, noted dark urine and swelling of the abdomen. This time he was admitted to another hospital where gallbladder and gastrointestinal roentgenograms were made. He was told that he "had a grapefruit-sized mass in the upper abdomen," which later disappeared. After discharge from that hospital, he had no complaints until 3 weeks prior to the present admission when he again developed swelling and pain in the abdomen. His urine again became dark and he experienced severe nausea. The day prior to admission he noted the knot in the upper abdomen which was painful.

Physical examination revealed a temperature of 102 F., pulse 108, and blood pressure 110/70. The sclerae were slightly icteric and the liver was slightly enlarged. A spherical mass about 12 cm. in diameter was palpated in the left upper quadrant of the abdomen. This mass was fixed, smooth, and tender and did not move with respiration.

Initial laboratory data revealed a serum amylase of 240 (normal up to 200 in this laboratory). The urine was positive for bile and negative for sugar. The hemoglobin was 12.8 grams, white blood cell count was 11,800 per cu. mm., red blood cell count 4.75 million, and the differential count was 70 per cent polymorphonuclear neutrophils, 25 per cent lymphocytes, 4 per cent monocytes and 1 per cent basophils. Prothrombin time was 19 seconds as

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compared with the control of 15. Thymol turbidity was negative. Total protein was 7.5 grams per cent with an albumin of 3.1 and a globulin of 4.4.

A chest roentgenogram revealed plate-like atelectasis in both lower lung fields. A gastrointestinal series revealed a mass which displaced the stomach posteriorly.

On the night of admission the mass was aspirated with a small gauge needle. Two hundred cc. of dark brown fluid were removed which had an amylase content of 584 units. Three days after admission, while shaving, the patient developed severe abdominal pain which radiated to the back. His abdomen was found to be rigid; the pulse was 100, but the blood pressure was normal. It was thought at this time that he had ruptured a pancreatic cyst, so he was transferred to surgery. Immediate laparotomy was done and about 1 liter of dark brown fluid was found in the general abdominal cavity. A perforation through the gastrocolic ligament measuring about 2.5 cm. in diameter was found in a cyst overlying the pancreas. The cyst was marsupialized to the anterior abdominal wall through a small left subcostal incision. The postoperative course was stormy and the patient experienced severe pain and intractable vomiting. After the first few days the cyst drained poorly and digital dilatation of the opening was necessary. He developed a smaller mass in the right upper quadrant which could not be drained with needle aspiration. His health gradually improved and on June 7, 1954 a cholecystectomy and sphincterotomy were performed. Intense inflammatory reaction in the area made the procedure difficult. The old cyst area appeared satisfactorily decompressed at this time. During the 3 weeks following this second operative procedure, a rather severe electrolyte disturbance developed, the direct result of heavy drainage from the T-tube in the common duct. On July 4 the tube was clamped and the patient dramatically improved. His jaundice gradually cleared. At the time of discharge on July 21, the left upper quadrant mass had all but disappeared and the serum bilirubin was 1.9. He was readmitted for 6 weeks in October, 1954 for recurrence of epigastric pain and nausea, and the serum amylase at that time was 241 units. There was no detectable recurrence of the cyst. As the pain cleared rather rapidly on Banthine, this was thought to represent a recurrence of pancreatitis. The patient had no further difficulty for several months and gained about 50 pounds in weight. He was readmitted to the hospital in April 1956 for epigastric pain of 24 hours' druation and at this time the serum amylase was 839. One week later after initial therapy with nasogastric suction, parenteral fluids and Banthine, the amylase was 46. The patient denied the recent intake of alcohol; however, his statement is subject to question. The patient was last seen March 21, 1957 when he was found to be well, working, and free of pain.

Case 2: A. J. B. This 60 year old white man was admitted to the Atlanta Veterans Administration Hospital on Jan. 10, 1956 complaining of inability to urinate. The temperature was 98.6 F., pulse 78, and blood pressure 120/80. The patient appeared older than his stated age. Examination of the heart revealed frequent premature ventricular contractions; the lungs were clear. No masses were felt in the abdomen; the liver and spleen were not enlarged. The prostate was rubbery to palpation and was moderately enlarged. A residual urine of 1000 cc. was present. A chest roentgenogram revealed tortuosity of the thoracic aorta and old pleural thickening on the left. An intravenous pyelogram revealed good excretion of the contrast media bilaterally without evidence of obstruction.

A bilateral partial vasectomy was performed. On January 20 a transurethral resection of the prostate was accomplished with removal of 15.75 grams of tissue. Immediately after surgery quinidine was started because of the marked increase in the frequency of the extopic ventricular contractions. A Levine tube was passed and gastric suction was instituted for nausea. The indwelling Foley catheter was removed on the fifth postoperative day. During the succeeding days, it was necessary to reinsert a Foley catheter several times for residual urine. On February 6 the patient's temperature rose to 102.4 F. and a large upper abdominal mass was detected for the first time. Once again, nasogastric suction was instituted, and intravenous fluid therapy and achromycin were begun. The next day his fever had subsided somewhat and a gastrointestinal series performed at this time revealed extrinsic pressure

FIG. 1. Roentgenogram showing displacement of viscera due to cyst in Case 2.

along the pars media and antrum of the stomach, displacing this organ anteriorly and to the left. There was noted also downward displacement of the second and third portions of the duodenum. There was no actual obstruction of the barium flow from the stomach. A pneumoperitoneum did not aid in the delineation of the mass and serum amylase studies were not done. This mass was thought to represent a pancreatic pseudocyst and elective surgery was planned as soon as his general condition permitted. From February 9 through February 13 the patient ran a febrile course with daily spikes approaching 103 F. As pyuria was present, it was thought that this temperature elevation was due to a urinary tract infection. On several occasions during this period the patient developed distention in the epigastrium, nausea and vomiting which required repeated insertion of the Levine tube and nasogastric suction. Partial decompression of the epigastric fullness could quite easily be obtained; however, the underlying mass did not appear to vary in size. On the morning of February 23 the nasogastric tube was removed and the patient was given surgical liquids by mouth. He ate breakfast and felt well. Shortly afterwards he got out of bed, and on doing so, fell to the floor and was noted to have a generalized tonic convulsion lasting approximately 1 minute, during which time he became intensely cyanotic. Immediately afterward he was found to be devoid of pulse and failed to respond to artificial respiration and to intracardiac ephinephrin. Clinically, death was ascribed to either myocardial infarction or a cerebrovascular accident.

At postmortem examination 5 liters of dark reddish-brown serosanguinous fluid was located in the peritoneal cavity. A cyst was present just anterior to and below the pancreas. This cyst measured 15–18 cm. in diameter and was very intimately attached to the midportion of the pancreas, which in this area was fibrotic and markedly atrophic. The cyst was also densely adherent to the stomach which was displaced upwards and to the right. Located at a point just below the gastrocolic mesentery and just to the left of the root of the mesen-

FIG. 2. Specimen in Case 2. Dark area is liver, Allis clamp is on the stomach and arrows point to perforations in the cyst.

tery were 2 small perforations, each measuring about 4 mm. in diameter. Whereas most of the cyst had a thick yellowish fibrotic wall, in the vicinity of these perforations it was quite thin and friable and appeared to be composed of nonviable tissue. Upon manipulation of the cyst, large quantities of remaining serosanguinous fluid squirted forth. The head and tail of the pancreas were quite large, nodular and fibrotic; but with recognizable areas of pancreatic parenchyma. The lesser peritoneal sac had been obliterated by the cyst. The pancreatic duct coursed all the way through the pancreas, although it was compressed and distorted in the midportion by the cyst. The cyst wall ranged from 4–8 mm. in thickness and it did not appear to have a definite lining.

Microscopic examination of the wall of the cyst revealed sclerotic granulation tissue heavily infiltrated with plasmocytes and histiocytes. The interstices were filled with hyalin material and in some places there were foreign body type of granulomatous reactions to cholesterol and blood pigment. Sections of the pancreas itself showed interstitial and periductal fibrosis.

Additional postmortem findings were atherosclerosis of the coronary arteries, interstitial myocardial fibrosis, severe atherosclerosis of the aorta, necrotizing inflammation of the trachea and bronchi due to aspiration of gastric contents, focal pyelonephritis, acute and chronic inflammation of the bladder and fibroglandular hyperplasia of the prostate.

DISCUSSION

Etiology. Formation of pseudocysts of the pancreas appears to be related to trauma and also to attacks of pancreatitis with or without associated gallbladder disease. Our first case was associated with recurrent pancreatitis, but the etiology of the second case is obscure. Detailed discussion of the development of pancreatic pseudocysts has been well covered in the literature and is not within the scope of this paper. These cysts have been noted as early as 24 hours after trauma and have been known to occur as late as 4 years.[2] The average time interval given by Meyer is 5 months. The rapidity of these accumulations could conceivably be influenced by the extent and severity of the reaction associated with the pancreatitis or by the caliber of the duct injured by trauma.

The factors leading to rupture are not always obvious. Trauma to the abdomen has a direct relation in a number of the reported cases. It is conceivable that trauma could also lead to damage of the wall of the cyst with a slowly developing necrosis and perforation at a later date. In one of our own cases, the aspiration of the cyst some 40 hours prior to rupture could well have played an important role in this complication. Spontaneous increase in intracystic pressure could result in pressure necrosis with ultimate perforation. Hemorrhage into the cyst would act in a similar manner.

Location. The greater proportion of pseudocysts are found lying within the lesser peritoneal sac and usually present in one of three sites: 1) between the stomach and transverse colon under the gastrocolic omentum, 2) between the stomach and the liver beneath the gastrohepatic ligament, 3) between the leaves of the transverse mesocolon. The site of perforation in all of Koucky's cases was either the gastrohepatic or the gastrocolic omentum. The perforations ranged from 0.5 to 1.5 cm. in size. In our patients the perforations were 2.5 and 0.5 cm. respectively and were found in the gastrocolic omentum in one instance and in the gastrohepatic ligament in the other.

Pathology. In reported cases unruptured cysts have contained from 15 cc. to 20 liters of fluid. Accordingly, the amount of fluid found in the peritoneal cavity after perforation depends both upon the size of the cyst and the dimensions of the perforation. The color of the cystic fluid may be chocolate, yellow, straw, milky, or hemorrhagic. The amylase determinations on the cyst content are usually elevated, but have a wide range of variation.

Complications of Pseudocysts. While it is thought that many of the smaller pseudocysts of the pancreas may continue throughout the lifetime of the individual without resulting in symptoms, the occurrence of complications is serious and usually demands emergency treatment.

1. Pyloric stenosis as a complication of these accumulations of fluid was noted by Meyer, who thought it resulted from a stomach tautly flattened over the cyst wall. This mechanism was well illustrated in an unruptured cyst recently seen at operation and seems to explain the clinical course of our second case.

2. Hemorrhage into the cyst is occasionally seen with sudden enlargement, acute symptoms and alterations in physical findings.

3. Rupture, either spontaneously or as a result of trauma, may occur into the gastrointestinal tract or into the free peritoneal cavity.

SYMPTOMS AND DIAGNOSIS

1. *Unruptured cysts.* The symptoms of upper abdominal mass, pressure and radiologic evidence of displaced viscera in unruptured cysts are common knowledge and will not be elaborated upon in this paper.

2. *Prodromal.* It has been suggested by Koucky that upper abdominal distress, nausea and vomiting are prodromal to actual perforation and their occurrence in the second of our cases should have alerted us to impending disaster.

3. *Symptoms of perforation.* Sudden excruciating pain with shock is the most dramatic symptom. These patients are acutely ill. The degree of shock varies from moderate to severe as illustrated by the fatal outcome of our second case. Possibly the degree of shock is related not only to the rapidity of leakage, but also to enzymatic and chemical nature of the cyst content. If the patient survives, the pain becomes generalized and a peritonitis supervenes. Obviously the disappearance of a previously recognized mass is a great diagnostic aid. A silent abdomen is the rule and abdominal rigidity is usually present. The white blood cell count is usually elevated and in one of Koucky's cases reached 23,000. Diarrhea has been consistently noted in those patients perforating into the intestine. The most frequently mistaken diagnosis is that of a ruptured ulcer.

Treatment. The extremely high mortality incident to the rupture of the pseudocyst of the pancreas emphasizes the desirability of prompt treatment of the unruptured cyst as soon as the diagnosis is established. Meyer is in accord with this point of view when he states, "This alarming mortality rate emphasizes the importance of early elective surgical intervention in pancreatic pseudocysts to preclude the possibility of rupture of the cyst.

When rupture occurs, shock should be treated vigorously and laparotomy performed as soon as possible with evacuation of all the spilled contents of the cyst. While definitive surgery at this time might be theoretically advisable, present experience indicates that surgery be limited to simple drainage or marsupialization if feasible.

SUMMARY

Perforation of pseudocysts of the pancreas, while rare, probably occurs more frequently than generally realized.

Complications of these cysts and the diagnosis of the complications are discussed.

The best treatment is prevention. Should rupture occur, adequate drainage by the simplest and quickest method, together with toilet of the peritoneal cavity is recommended.

Two new cases are reported.

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EDITORIAL

CLINICAL EVALUATION

While no one would care to be limited again by the earlier inaccurate laboratory procedures, their inadequacy was realized and the importance of clinical evaluation was appreciated and utilized.

With many more procedures now available a dependency upon them to spell diagnosis and treatment at the neglect of clinical judgment must be combatted.

For example there are some who believe that if a gallbladder can be visualized with dye and if no stones are demonstrable then disease of that organ is minimal or absent. Such of course is not true. One should have the courage of his convictions if the symptoms are those of cholecystitis and a careful appraisal has been made to eliminate other etiologic factors.

All of us have removed stones that were not demonstrated roentgenologically. We know too that colicky-like pains can be produced by the so-called "strawberry gallbladder" due to cholesterosis. Further, it is not necessarily true that because a gallbladder fills well with the dye it will empty just as satisfactorily. Operations for the relief of symptoms of gallbladder disease when at surgery there is found a disproportionately small cystic duct or one distorted by kinks and angulation have given relief to patients who were denied surgery by those who demand roentgenologic confirmation of the diagnosis as an absolute criterion before operation is advised.

Tissue committees and other evaluation groups have undoubtedly improved the quality of surgical service, but servile deference to fear of their questioning may cause uniformity and its resulting mediocrity in instances where courage is needed to offer relief.

Again surgery is sometimes unnecessarily deferred or denied cardiac patients. Too much dependence is placed upon electrocardiographic tracings and similar tests of cardiac function. In these times of specialized anesthesiology and early postoperative ambulation few patients who have cardiac conditions should be deprived of needed surgery. As a matter of fact, the extra precautions taken in the surgical care of such patients seems to make them less likely to have cardiac arrest, anoxemia, etc. than normal risks. Few cardiac cripples die on the operating table. Many have a decrease of cardiac symptoms after the removal of a diseased gallbladder, toxic thyroid, and other lesions of that type. A fairly satisfactory test of cardiac function would seem to be the ability to engage in even minimal activity. In patients less compensated a calculated risk must be taken when the expected prognosis of the surgical disease is extremely grave.

Appendicitis may be among the simplest or most difficult diagnoses to make. This is particularly true in children. Surgeons too jealous of the accuracy of their diagnosis sometimes forget how rapidly the symptoms can change in this group of patients. Waiting for all the classical symptoms may result in disastrous delay. Early operation in doubtful cases may show in some instances only mesenteric

adenitis but rarely do symptoms of that condition appear again after the appendix has been removed.

Increasing longevity necessitates more surgery of the aged and the importance of age per se should not be over evaluated.

These comments are not directed against the utilization of all available laboratory help. Neither are they intended to encourage hasty diagnosis with inadequate clinical study. They are offered to stimulate surgeons to make a thorough evaluation of each case and to proceed with surgery in those instances where it is thought to be indicated. The patient must always be considered as a sick person and not as a composite of laboratory reports.

Such a plan of surgical treatment may at times call for considerable courage but timidity is not an attribute of the competent and useful surgeon.

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BOOK REVIEWS

The editors of THE AMERICAN SURGEON *will at all times welcome new books in the field of surgery and will acknowledge their receipt in these pages. The editors do not, however, agree to review all books that have been submitted without solicitation.*

Liver, Biliary Tract and Pancreas. By FRANK H. NETTER, M.D., Ciba Company.

This book represents Part III of Volume 3, The Digestive System, of The Ciba Collection of Medical Illustrations. It consists of 165 pages with 133 full color plates. An adequate and concise text accompanies the illustrations. The excellent illustrations by Dr. Netter are outstanding in presenting the normal and pathologic conditions observed in this portion of the digestive system. The sections of the book are: Normal Anatomy; Physiology and Pathophysiology, including Hepatic & Pancreatic Tests; Diseases of the Liver; Diseases of the Gall Bladder & Bile Ducts; Diseases of the Pancreas; and a Bibliography. The previously difficult interpretation of physiology, pathology, and functional tests is markedly simplified by the material and method of presentation as observed in this section of the book.

Dr. Netter and his six consultants and contributors are to be congratulated on preparing an excellent and most useful contribution to the literature on this subject. They have produced a comprehensive, readable book that embraces the current concepts of the liver, biliary tract, and pancreas in health and disease. The acquisition of this book is recommended to all who are interested in this topic.

ROGER D. SCOTT, M.D.

Orthopedic Surgery in Infancy and Childhood. By ALBERT B. FERGUSON, JR., M.D., Williams and Wilkins Co., Baltimore, Md.

This book is written primarily by Dr. Ferguson with some sections contributed by four orthopedists and one pediatrician. It is well written and made quite readable by good organization and the use of many (504) illustrations which are primarily roentgenograms and photographs. The chapters are: The Foot; The Knee; The Hip; The Spine; The Neck; The Upper Extremity; Affections of Bone; Affections of Muscle; Neurogenic Affections; and Malignant Tumors of Bone. Adequate references are supplied following each topic discussed rather than following each chapter. Many unusual and infrequently seen orthopedic problems are presented; however, fractures and detailed operative technics are omitted.

The author states that "no syndrome, photograph, or roentgenogram is presented which was not personally seen by the author." This should be some indication of his experience in this field.

This book is considered extremely useful for the orthopedic surgeon and probably the pediatrician, but because of its highly specialized content, it is not recommended for use by the average general surgeon.

ROGER D. SCOTT, M.D.

Diseases and Disorders of the Colon. By ANTHONY BASSLER, M.D., Charles C Thomas, Springfield, Illinois.

This monograph of 217 pages represents Dr. Bassler's personal points of view on diseases of the colon with emphasis on diagnosis. A variety of unusual and infrequently seen conditions are presented. The book is well illustrated, principally with roentgenograms and photographs. The chapters are: Appendicitis; Intestinal Obstruction; Colitis in General; Parasitic Diarrheal Infestations; Chronic Diarrheas; Chronic Biotoxic Intestinal States; Tumors; Ulcers; Low Grade Infective States; Parasitic Disorders; Anatomic Disorders and So-Called Functional States.

Many topics are covered, but very few are adequately discussed. This book would be of primary interest for the internist; however it leaves much to be desired from the standpoint of thoroughness. It would probably be of no interest to the surgeon.

ROGER D. SCOTT, M.D.

TRACHEOTOMY: A CLINICAL AND EXPERIMENTAL STUDY

PART III*

THOMAS G. NELSON, MAJOR, M.C., U.S. ARMY

CHAPTER IV. EXPERIMENTAL MATERIAL

Introduction and Purpose of the Study

From the time of the earliest tracheotomies, interest has been expressed in the healing of the tracheotomy wound. Indeed, the fear that the wound would not heal greatly retarded use of the operation and the fear that divided cartilage would not unite caused early surgeons to open the trachea between the rings. This technic was followed until 1718, when Heister first practiced vertical incision of the trachea because he found the transverse opening to be impractical for the removal of foreign bodies. Almost 100 years later, Lawrence first suggested that a hole be made in the anterior tracheal wall so that breathing could be accomplished in the event the cannula could not be left in. This method was later practiced by Hall,[125] Diffenbach[226, 279] and others.[214] The excision technic was used at that time for two main reasons, to dispense with the cannula altogether or to create more space for it; although Diffenbach also pointed out the advantage of excision over simple incision in lessening infection and necrosis of cartilage. Porter,[214] in 1864, enumerated nearly every present known clinical advantage of the excision method and commented that he could find no disadvantages or delay in healing due to this technic. The excision technic, according to Porter, was not widely used, since it was said to increase operative difficulties and to cause narrowing of the trachea upon healing of the wound. Near the turn of the twentieth century, the excision technic was used sporadically in operations on the head and neck, in which the Trendelenburg tube was passed through the tracheal opening for anesthesia;[3, 20, 52, 196] but it was not otherwise reported except in the technic advised by Martin,[182] in which no cannula was used.

In 1911 Thost[266] advised the excision method, since, from both clinical and experimental study, he had noticed that an opening which allowed room for the cannula was attended by less deformity and necrosis of cartilage, and subsequently by better healing. By this time, however, Jackson[139] had published his method for both emergency and elective tracheotomy and the advantages of the excision method were overlooked in the wave of acceptance for Jackson's unified technic which included a vertical incision of the trachea. Jackson[139] had no particular objection to the excision technic and agreed to its usefulness, but, for teaching purposes, he believed it to be an unnecessary refinement added to an operation already overburdened with technical variations.

In more recent years, the excision technic has again been recommended.[131, 195, 278, 279] Hill[131] advises it because of the safer airway provided during exchange of the cannula. Waldapfel[278, 279] uses the excision method, since he believes that

* *Editor's note:* This is the final installment of Dr. Nelson's comprehensive review which, because of its length, has been presented in three consecutive issues of The American Surgeon. Parts I and II appeared in the July and August, 1957, issues.

the insertion of a cannula into a slit in the tracheal wall causes distortion, buckling, and pressure necrosis of the cartilages. According to Waldapfel, these changes not only decrease the size of the lumen during the time the cannula is in place, but also may result in permanent narrowing of the trachea.

Although it has been pointed out, both in the clinical study and in the review of the historic aspects of tracheotomy, that there are many advantages of the excision method of tracheotomy, the clinical study and the writings of present-day authors would indicate that this valuable measure is seldom utilized. As a further effort to point out the merits of this method a series of observations, both in patients and in laboratory animals, was undertaken with the view in mind of comparing the healing process of the excision method with the other methods of opening the trachea. Emphasis was placed on long-term healing in the laboratory animal, using gross measurements as evidence of distortion, collapse, or stenosis of the airway.

Although it is not definitely known when cricothyroidotomy was first used, Vicq d'Azyr, Heuter, and Roux, in the early nineteenth century, were the first surgeons to advise that the operation be used more frequently in place of tracheotomy.[48, 234, 242] Cricothyroidotomy became widely used because the danger of fatal hemorrhage was reduced and it was possible to complete the operation quickly, a matter of great importance due to the lack of anesthesia. It was not until 1873, after hundreds of such operations had been done, that Rydygier[234] first called attention to the fact that laryngeal stenosis appeared more frequently following the high operation. He, and later Colles[54] in 1886, were the first to point out the importance of an intact cricoid cartilage in preserving the normal framework of the larynx. Colles collected 76 cases of laryngeal and tracheal stenosis and commented on the close association of cricothyroidotomy and high tracheotomy to stenosis in certain cases, although he believed that the chief cause of stenosis was the presence of the cannula which caused distortion and hypertrophy of the cartilages. Both Rydygier and Colles reported cases in which low tracheotomy had to be done for relief of stenosis following the high operation. Despite these admonitions, cricothyroidotomy continued to be a popular operation until Jackson[142] reported that in 83 per cent of his cases laryngeal stenosis resulted from high tracheotomy. It should be pointed out that the great majority of patients reported by Rydygier, Colles, and Jackson were children in whom the cannula had been neglected for many months. The greater susceptibility of children to erosion of the cricoid cartilage, infection, excessive granulation tissue, fibrosis, and eventual collapse of the airway has since become more widely publicized.[163, 224, 225] On the other hand, Figi[88] has stated that, in his experience, stenosis did not occur following the high operation even if the cannula was used, provided the cricoid cartilage was not damaged at the time of surgery. Others[124, 219, 278] have stated that they believe cricothyroidotomy is a safe operation, especially if used for an airway for the least possible time and if a cannula is not employed. Even today, however, special cannulas are still being designed for use with the operation.[72] Thus, it seems that there is continued clinical use of cricothyroidotomy despite the infamous reputation of the operation in years past.

FIG. 26. Autopsy specimen demonstrating an unusual tracheotomy opening through the thyroid cartilage. Operation was performed elsewhere and patient was not included in this study.

Figure 26, taken from a patient whose operation was performed elsewhere and who is not included in the clinical study, gives ample proof that various forms of high tracheotomy are still being utilized.

In addition, there are recent hints that cricothyroidotomy may be more commonly practiced in the future. It has been suggested that the operation is simple enough to be taught to nonprofessional personnel for use in certain situations, mainly combat and mass casualties.[293] In fact, the Navy Bureau of Medicine has recently released a motion picture film demonstrating how a hospital corpsman might perform the operation on the battlefield. Such recommendations disregard one important fact: that the surgical judgment behind the decision to open the airway artificially is often more important than the technic of the operation.

Unfortunately, there was no opportunity in the clinical study to observe the advantages or disadvantages of cricothyroidotomy. Therefore, a series of experimental observations was undertaken in an effort to determine any possible ill effects of the operation. Emphasis was on the determination of laryngeal stenosis by selected measurements made after long-term healing.

During the course of the clinical study certain advantages of tracheotomy were uncovered in which the physiologic changes behind these advantages were not known. As Blakemore[24] has pointed out, many of these physiologic changes associated with the newer uses of tracheotomy are not measureable. However, Carter,[40, 41, 42] in his unique work on tracheotomy in chest injuries, has been able

to demonstrate experimentally measurable changes in respiratory pressure which reflect the physiologic advantages of tracheotomy he describes. It was determined to perform a limited series of experimental observations in which certain physiologic advantages of tracheotomy were measured, namely, the use of tracheotomy as a vent.

Experimental Background

Schueller,[226, 241] in 1880, was the first to perform an experimental study on healing of the incised trachea. He found that a simple incision of the trachea in guinea pigs healed uneventfully. After healing was complete, microscopic examination showed complete regeneration of the epithelium, mucosa, and submucous glands and revealed that the cut edges of the cartilage united by fibrous tissue in the same manner as the skin and subcutaneous incision. There was no union by growth of cartilage. These findings have been repeatedly confirmed by Mori[192, 193] in 1932 and 1936, Peitratoni[211] in 1928, Richards and Glenn[227] in 1932, Taffel[258] in 1940, and Daniels[64, 65] in 1948 and 1950.

Thost[266] in 1911 performed the first experimental and clinical study of tracheal stenosis and the relationship of the use of a tracheotomy cannula to wound healing. He discovered, as had long been suspected, that one of the critical factors in promoting stenosis and delayed healing was the introduction of the cannula into the opening. Thost described the main causes for stenosis as distortion of cartilage, the formation of excess granulation tissue, and the formation of scar tissue. All these factors were aggravated by the prolonged use of an oversized cannula and were greatly accelerated when the cannula was placed through a slit in the tracheal wall rather than a defect.

Mori[192, 193] performed an interesting group of experiments on rabbits in which he determined that the subperichondrial excision of pieces of three or more cartilaginous rings of the trachea resulted in severe stenosis. If pieces of only two or less cartilages were excised then no stenosis developed. The defects created were largely healed by scar, but in some instances new growth of cartilage took place. Since it is seldom necessary to excise more than a portion of one cartilaginous ring in order to gain ample room for the cannula, there is little danger of stenosis from this cause.

Taffel[258] and Daniels[64, 65] performed experiments with the healing of defects in the tracheal wall using fascial grafts. Healing was found to proceed uneventfully, and within a period of one month nearly complete regeneration of the mucosal epithelium and submucous glands was present, while the fascial grafts became replaced with scar tissue. No stenosis or other deformity was noted.

Richards and Glenn[227] have presented the most complete study of the tracheotomy wound to date. They were the first to test healing of the various types of tracheotomy incisions with and without the cannula. They likewise recorded uneventful healing without stenosis or distortion in simple incised wounds. They noted that the defect was closed by connective tissue growth without any evidence of cartilage regeneration. The addition of the cannula had a definite delaying effect on healing and increased the amount of connective tissue formed about

it. With an adequate opening for the cannula and no pressure against the edges of the cartilage, there was very little tendency toward the formation of granulations large enough to cause appreciable encroachment on the tracheal lumen. In simple tracheal defects, healing was rapid and there was very little tendency for the superficial tissues to fall into the opening and produce obstruction.

The experiments of Richards and Glenn, although the most complete and worthwhile work yet done on healing of the tracheotomy wound, did not give the answer to certain problems. Most of their experiments were concerned with the microscopic appearance of the healing tracheotomy wound under short-term conditions, usually less than two weeks. Gross inspection for evidence of distortion and stenosis at the tracheotomy site was made, but preoperative and postoperative measurements were not taken. The experiments were concerned mainly with healing of cruciate and vertical incisions and no experiments involving the cricoid cartilage were performed.

In contrast, the experimental method used in this study was designed mainly to show the results of long-term healing with all the common types of tracheal incisions and with cannulas placed in two chief locations—the cricothyroid space and the the usual site of tracheotomy. The criteria to be used for evidence of stenosis or distortion were gross measurements taken preoperatively and after eventual healing.

Materials and Methods

Healthy mongrel dogs of unknown age but with the general appearance of young adults were used in these experiments. Their weights ranged from 7 to 14 kg. Weights and heights were checked before and after the experiments for evidence of growth. Larger and presumably older animals were selected for the long-term experiments to reduce the effect of growth on the measurements to be described.

Anesthesia was obtained by using intravenous sodium pentobarbital (Nembutal) in dosages of 30 mg. per kg. of body weight. No inhalant anesthetic agents were used.

Aseptic surgical technic was utilized. The dogs' necks were shaved and prepared with merthiolate, and sterile gloves were worn after scrubbing the hands with septisol for two minutes.

A midline vertical incision was made over the region of the trachea and larynx, and the strap muscles of the neck were separated in the midline to expose the thyroid and cricoid cartilages and the upper portion of the trachea. Careful hemostasis was obtained and the thyroid gland was not disturbed. Measurements of selected areas of the trachea and larynx were made for comparison after healing.

Appropriate incisions of various types (figure 27) were then made into trachea or larynx, and the standard Jackson tracheotomy cannula was put in place and held by heavy twine cord tied around the neck. The size of each cannula was carefully correlated to the size of the tracheal lumen (calculated from the external diameter of the trachea) so that unusual discrepancies were avoided. The wound

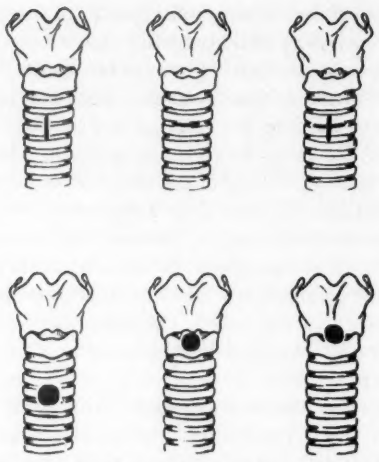

FIG. 27. The six types and locations of incisions used in the experimental study.

was closed with a single layer of running silk suture placed through the skin only. No blood replacement or antibiotic therapy was used.

The cannulas were kept clean and free of debris for the first 24 hours, but after that, no special care was given to the cannula. Since it was impossible to keep all cannulas unplugged at all times, it was judged that a better control measure would be to allow the cannula to become crusted or plugged in the natural course of events, so long as the time and effect of this occurrence was noted in the sequence of healing. The cannula was allowed to remain in place for a predetermined period, then removed. After the cannula was out, a preselected period for healing was allowed to elapse, after which the animals were sacrificed and comparative postoperative measurements made to determine if stenosis or distortion of the airway had occurred.

The trachea and larynx were again exposed through a new incision along the lateral side of the neck. The area of skin, subcutaneous tissue, and muscles adherent to the healed tracheotomy site was left attached during this dissection (figure 28). Certain external measurements were taken with the trachea *in situ*, following which the larynx, trachea, and esophagus were removed *en bloc*. The esophagus and other attached tissues were carefully dissected from the trachea and larynx and the balance of the measurements taken while the specimen was still fresh. The specimens were then preserved in 10 per cent formalin for later microscopic section in selected experiments.

During the interval between removal of the cannula and final healing, notation was made of the time lapse before the fistula closed as evidenced by cessation of air leak. The animals were frequently observed for any change of barking, and difficulty of swallowing or breathing. The wound was inspected frequently for infection, unusual amounts of granulation tissue, and scarring. Laryngoscopy and bronchoscopy were performed in several animals during the healing phase to

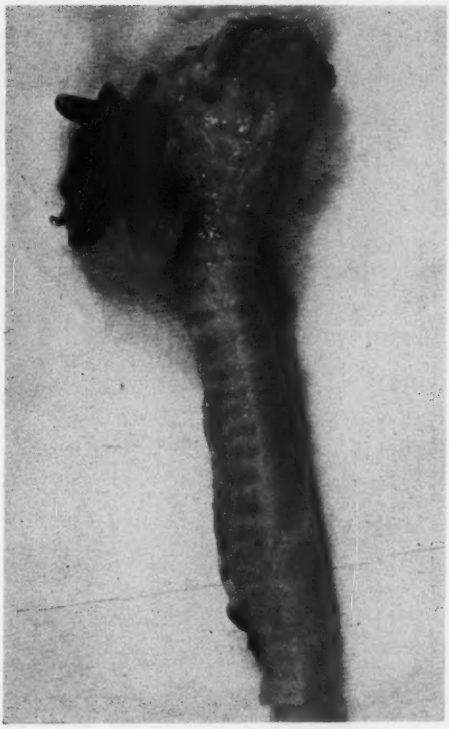

FIG. 28. Trachea and larynx of dog, demonstrating marked anteroposterior angulation of trachea at site of tracheotomy. Cannula placed through a transverse incision made in the interspace below second tracheal ring. Cannula produced severe tracheal irritation from rubbing on anterior tracheal wall.

check for stenosis or the presence of granulation tissue protruding into the lumen of the trachea.

Types of incisions. The types of incisions used in series 1, 2, and 3 are shown in figure 27. Care was taken to avoid incisions too large or too small for the size cannula used. The vertical incision was placed so that cartilages 2 and 3 or 3 and 4 were excised. The cruciate incision was located in the same manner with the transverse limb placed in the interspace between the divided cartilages. The transverse incision was placed in the interspace between cartilages 2 and 3 or 3 and 4. As will be pointed out, only a limited number of this type of incision was used. With the excision method, a central portion of one cartilage, usually the third or fourth, was excised together with portions of the adjoining interspaces. It was not necessary to excise more than one cartilage to allow ample room for the cannula. For the sake of simplicity the excision method will be referred to subsequently as the window incision. In the experiments with cricothyroidotomy, two types of incisions were used. The first was a transverse incision through the

cricothyroid membrane, and the second was a vertical incision through the cricoid cartilage. In one instance a piece of the cricoid cartilage was removed to allow room for the cannula.

Methods of measurement. In series 1 and 2 the following five measurements were made preoperatively and after final healing: (1) outside diameter of trachea; (2) thickness of wall; (3) lumen of trachea; (4) vertical length covered by five tracheal rings with inclosed interspaces; and (5) width of membraneous portion of trachea.

In the cricothyroidotomy experiments the following five measurements were made: (1) outside diameter of larynx at cricoid cartilage level; (2) width of cricoid cartilage; (3) thickness of cricoid cartilage; (4) diameter of lumen at cricoid area; and (5) length from top of thyroid cartilage to bottom edge of cricoid cartilage.

All measurements were expressed in millimeters and were taken with the aid of a micrometer, calipers, and metal rule. The final figures were rounded off to the nearest millimeter, since by muiltple tests with the instruments used the maximum range of error was found to be approximately ½ mm. The measurements were designed to reflect narrowing, shortening, stenosis, or other distortion of the airway.

The methods of taking the measurements are shown in figure 29. Some comment should be made on these methods. The length of the trachea was measured to include the first five tracheal rings beginning at the bottom edge of the cricoid cartilage. The outside diameter of either the trachea or larynx was taken at the site of the tracheotomy opening, as was the measurement of the lumen and posterior membraneous wall. The measurement of the lumen was made in an anteroposterior direction, using a slender metal rule placed through

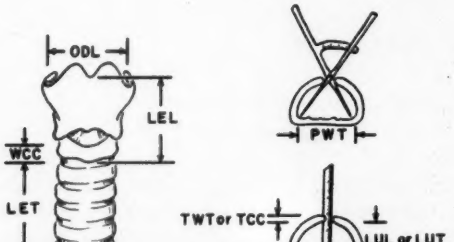

FIG. 29. Measurements used in experimental series to compare preoperative and post-healing size of larynx and trachea. Measurements were taken in millimeters with calipers and metal rule.

the tracheotomy opening. In life, this measurement was sometimes difficult to estimate because of motion from respiration. The posterior wall of the trachea was measured through the tracheotomy opening with the aid of fine calipers having an outside scale. The thickness of the tracheal wall was taken at the thickest point adjacent to the tracheotomy site. The width of the cricoid cartilage was taken as indicated, and its thickness was measured through the adjacent opening.

All these measurements were taken several times for the sake of accuracy. The measurements were again repeated in the fixed specimens as an additional check on accuracy. These latter measurements were not used in the statistical calculations.

Experimental series. First series:—Eight animals were used as a control series to test the effect of each of the four types of tracheal incisions on healing and to rule out the possibility that incision of the trachea without the use of the cannula would produce any measurable changes. In addition, this series was used to test the best sites for measurement and to test the accuracy of the measurements taken. Two animals were used for each incision. Healing was allowed to progress for 30 days in four animals, each with one of the four incisions, and for 60 days in a similar group of four animals. Measurements were taken preoperatively and posthealing. Appropriate microscopic sections were made to study the healing process.

Second series:—Fourteen animals were used. It was originally planned to use four groups of animals. Each group was to contain four animals, each one with a different type of incision, according to the following plan:

Group 1. Cannula left in 10 days, removed, healing checked 20 days after removal.

Group 2. Cannula left in 20 days, removed, healing checked 40 days after removal.

Group 3. Cannula left in 30 days, removed, healing checked 60 days after removal.

Group 4. Cannula left in as long as tolerated, or until displaced, or up to four months, removed, healing checked four to six months after removal.

However, it was soon learned that the animals did not tolerate the cannula when placed through a transverse incision. The first two dogs tested in this manner developed extreme respiratory irritability manifested by a rasping type cough and constantly made efforts to extrude the cannula. The first dog dislodged the cannula on the third day after tracheotomy, and although it was replaced and the neck retainer reinforced, the cannula was again out in 24 hours. The second dog developed the same symptoms, and in addition refused food and water and died on the eighth day. Examination after death revealed the trachea to be angulated in an anterioposterior direction with the end of the cannula rubbing the anterior tracheal wall (figure 28). Although a shorter cannula was used on the third dog, the same difficulty developed immediately. The next day the wound was reopened and the incision converted to a cruciate type. Testing of the transverse type incision was discontinued.

The vertical, cruciate, and window incisions were used in the remaining 12 dogs according to the original plan. Only one animal was not available for final testing. All animals tolerated the cannula well. A few dogs dislodged their cannulas before the prescribed time. In some the cannula was replaced immediately, but in others the loss was not noticed until the fistula had almost closed. In this event, the animal was transferred to another series more suitable to the time factor involved. Since the long-term experiments were started first, this transfer did not affect the distribution of animals in each group; and since the time factors were arbitrarily selected, a few days' difference in the length of time the cannula was in place was considered to be statistically negligible.

Third series:—Six animals were used. Three had cannulas placed through the cricothyroid space after transverse incision of the membrane, while three had cannulas placed through the cricoid cartilage after vertical incision of this structure. A defect was made in the cricoid cartilage in one animal. Three groups of two animals, each with a different incision, were tested according to the time factor outlined for the first three groups of series 2. The animals tolerated the cannulas well, although two of them dislodged the cannulas several days before the alloted time of testing. In general, smaller tubes had to be used than in the experiments in the second series because of the small size of the cricothyroid space and the rigidity of the cricoid cartilage.

Fourth series:—These experiments will be discussed separately.

Experimental Data

Interpretation of measurements. The measurements taken preoperatively and following healing, and the differences between the two, are shown for series 1, 2, and 3 in tables 8, 9, and 10, respectively. The problem of how best to evaluate these figures in terms of stenosis and distortion of the airway arose. After many systems were evolved and discarded, the following method was selected: The figures in the change columns (tables 8, 9, 10), indicating a decrease in the outside diameter of the trachea, an increase in thickness of the wall adjacent to the tracheotomy site, a decrease in the lumen of the trachea, and a decrease in the width of the posterior wall, were added together. This sum was then compared to the original measurement of the outside diameter of the trachea to establish a numerical index according to the following formula:

$$\frac{\text{Change in: ODT} + \text{TWT} + \text{LUT} + \text{PWT}}{\text{Original measurment of ODT}} = \text{Index of stenosis}$$

Each of the four measurements of change shown above reflects the tendency for narrowing of the airway. The sum of these measurement, when compared to the original outside diameter of the trachea for a given animal, yields a numerical index which takes into account the differences in size of the animals and allows comparison from one animal to another of the various factors to be tested. It was originally intended that the length of the trachea or larynx would be used to establish a numerical index of stenosis. However, this measurement showed greater variability from one animal to another than did the measurement of the

TABLE 8

Comparison of preoperative and posthealing measurements of trachea, using four types of incisions without a cannula

Dog no. and incision	Measurements (in millimeters)*					Stenosis or distortion
	ODT	TWT	LUT	PWT	LET	
Group 1: 30 Days' Healing						
1. Vertical						
Preoperative	16	2	10	9	24	None
Healed	15	3	10	9	22	
Change	1	1	0	0	2	
2. Transverse						
Preoperative	17	2	12	9	28	None
Healed	17	2	11	9	27	
Change	0	0	1	0	1	
3. Cruciate						
Preoperative	26	3	21	15	28	None
Healed	26	5	19	15	27	
Change	0	2	2	0	1	
4. Window						
Preoperative	22	3	17	14	22	None
Healed	22	5	15	14	21	
Change	0	2	2	0	1	
Group 2: 60 Days' Healing						
5. Vertical						
Preoperative	25	3	20	16	23	Questionable
Healed	24	5	18	15	21	
Change	1	2	2	1	2	
6. Transverse						
Preoperative	23	3	19	13	20	None
Healed	23	3	18	12	20	
Change	0	0	1	1	0	
7. Cruciate						
Preoperative	18	2	13	10	22	None
Healed	19	3	13	10	21	
Change	1	1	0	0	1	
8. Window						
Preoperative	21	3	16	12	26	Questionable
Healed	20	5	14	12	26	
Change	1	2	2	0	0	

* ODT = outside diameter; TWT = thickness wall; LUT = lumen; LET = length; PWT = posterior wall.

outside diameter. The measurements of length were therefore used as a further check on the accuracy of the other measurements and, in certain instances, gave further evidence of over-all distortion of the airway.

For the purposes of comparison, an arbitrary scale was devised to indicate the degree of change that occurred. This scale was arranged according to an increase in size of the numerical index of stenosis as follows: (1) up to 25, none or question-

TABLE 9

Comparison of preoperative and posthealing measurements of trachea, using four types of incisions with a cannula

Dog no. and incision	Measurements (in millimeters)*					Stenosis or distortion
	ODT	TWT	LUT	PWT	LET	
Group 1: Cannula in 10 Days; Healing, 20 Days						
9. Vertical						
Preoperative	17	2	12	9	25	Moderate
Healed	14	5	9	7	22	
Change	3	3	3	2	3	
10. Transverse						
Preoperative	22	3	16	12	21	Experiment
Healed	—	—	—	—	—	discontinued
Change	—	—	—	—	—	
11. Cruciate						
Preoperative	20	3	14	11	25	Moderate
Healed	17	6	10	9	23	
Change	3	3	4	2	2	
12. Window						
Preoperative	25	4	19	15	29	
Healed	23	6	14	14	27	Minimal
Change	2	2	5	1	2	
Group 2: Cannula in 20 Days; Healing, 40 Days						
13. Vertical						
Preoperative	26	4	20	16	30	Moderate
Healed	23	7	16	13	27	
Change	3	3	4	3	3	
14. Transverse						
Preoperative	26	3	18	15	24	Experiment
Healed	—	—	—	—	—	discontinued
Change	—	—	—	—	—	
15. Cruciate						
Preoperative	21	4	17	13	27	Minimal
Healed	18	6	15	11	26	
Change	3	2	2	2	1	
16. Window						
Preoperative	16	2	11	10	20	Moderate
Healed	15	6	8	9	20	
Change	1	4	3	1	0	
Group 3: Cannula in 30 days; Healing, 60 Days						
17. Vertical						
Preoperative	25	4	20	15	28	Moderate
Healed	20	7	15	12	27	
Change	5	3	5	3	1	
18. Cruciate						
Preoperative	26	4	19	16	30	Moderate
Healed	22	7	15	14	27	
Change	4	3	4	2	3	

TABLE 9—*Continued*

Dog no. and incision	Measurements (in millimeters)*					Stenosis or distortion
	ODT	TWT	LUT	PWT	LET	
19. Window						
Preoperative	22	3	17	13	25	Moderate
Healed	19	5	12	9	22	
Change	3	2	5	4	3	
Group 4: Cannula in 4 Mo.; Healing, 6 Mo.						
20. Vertical						
Preoperative	26	3	18	15	26	Marked
Healed	21	8	12	11	23	
Change	5	5	6	4	3	
21. Cruciate						
Preoperative	25	4	19	14	29	Marked
Healed	21	10	10	11	26	
Change	4	6	9	3	3	
22. Window						
Preoperative	26	4	20	17	31	Moderate
Healed	23	8	15	14	30	
Change	3	5	5	3	1	

*ODT = outside diameter; TWT = thickness wall; LUT = lumen; LET = length; PWT = posterior wall.

able change; (2) 25 to 50, minimal change; (3) 50 to 75, moderate change; and (4) 75 or over, marked change.

The same formula was used for the experiments dealing with the larynx, except that only three instead of four measurements were available from which to calculate the numerical index of stenosis, since the larynx has no posterior wall comparable to that of the trachea. In these instances, minimal changes occurred when the index was below 33, moderate changes were reflected in the range of 33 to 50, and marked changes were apparent when the index was over 50. Because of the difference in location of the tracheotomy wound, the different anatomic site to be measured and the different indices obtained from the measurements, stenosis of the larynx—strictly speaking—was not statistically comparable to stenosis of the trachea. Nevertheless, since the index of stenosis measurements correlated so closely with the gross observations, such comparisons as needed were made on the basis of the measurements.

It should be clearly pointed out that these indices *are not* a measure of the actual degree of stenosis occurring in a given animal, but serve only as a basis for comparison from one animal to another of the changes found on gross and microscopic examination. The correlation between the index of stenosis indicated by the measurements and that amount of stenosis evident on gross and microscopic examination was quite consistent. In those animals whose measurements indicated questionable or no change, there was no evidence of change on visual examination (figure 30*A*). When the measurements indicated that moderate changes had occurred, stenosis began to be evident grossly (figure 30*B*). When

TABLE 10

Comparison of preoperative and posthealing measurements of larynx, using two types of incisions with a cannula

Dog no. and Incision	Measurements (in millimeters)*					Stenosis or distortion
	ODL	TCC	LUL	WCC	LEL	
Group 1: Cannula in 10 Days; Healing, 20 Days						
23. Cricoid cut						
Preoperative	24	3	12	5	26	Moderate
Healed	19	4	9	3	23	
Change	5	1	3	2	3	
24. Cricothyroidotomy						
Preoperative	26	3	16	6	29	Minimal
Healed	24	5	13	5	26	
Change	2	2	3	1	3	
Group 2: Cannula in 20 Days; Healing, 40 Days						
25. Cricoid cut						
Preoperative	30	3	19	6	33	Moderate
Healed	25	5	14	3	30	
Change	5	2	5	3	3	
26. Cricothyroidotomy						
Preoperative	28	3	17	6	30	Marked
Healed	23	7	12	3	26	
Change	5	4	5	3	4	
Group 3: Cannula in 30 Days; Healing, 60 Days						
27. Cricoid cut						
Preoperative	32	4	20	7	34	Marked
Healed	25	8	14	0	30	
Change	7	4	6	7	4	
28. Cricothyroidotomy						
Preoperative	31	4	18	7	35	Moderate
Healed	25	7	13	1	28	
Change	6	3	5	6	7	

* ODL = outside diameter; TCC = thickness cricoid cartilage; LUL = lumen; WCC = width cricoid cartilage; LEL = length.

the numerical index denoted a marked change, then distortion and stenosis of the airway were readily apparent (figure 31).

Gross and microscopic changes. Series 1:—The tracheotomy wounds in these eight animals healed without incident regardless of the type of incision used. It is evident from the measurements shown in table 8 that no stenosis or distortion resulted. Examination at the end of 30 days revealed that the wound site could hardly be detected and on microscopic examination a thin line of scar tissue was the only evidence that the cartilage had been cut. The incised cartilage showed little change except that the cut edges became rounded and the adjacent cartilage cells became slightly distorted. There was no evidence of cartilage regeneration.

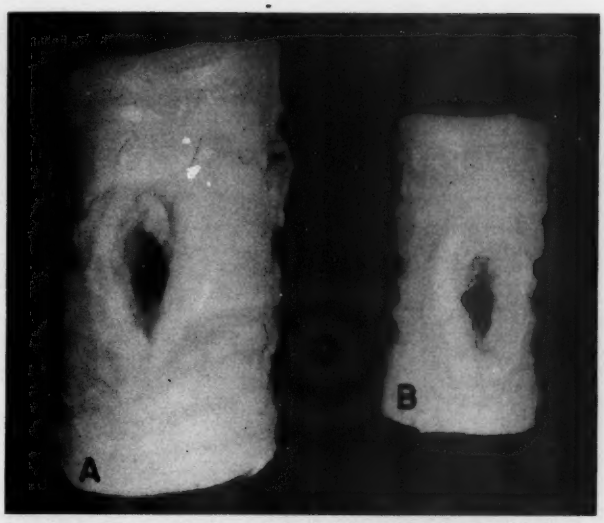

FIG. 30. Tracheas of dogs, showing minimal (*A*) and moderate (*B*) degrees of stenosis following tracheotomy. The tracheotomy site has been reopened to take measurements.

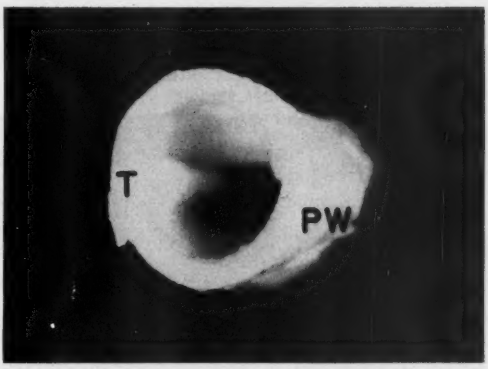

FIG. 31. Trachea of dog, showing severe degree of stenosis following tracheotomy. Note decrease in size of lumen from piling up of scar tissue at site tracheotomy (*T*), and decrease in width of posterior wall (*PW*).

The mucosal epithelium regenerated almost completely by 30 days except that the epithelial cells remained without cilia for a while longer. If the window incision was employed, then the line of healing by scar was somewhat broader, and the cut ends of the cartilage were more widely separated. There did not appear to be any tendency for the overlying tissues to invaginate into the opening and encroach upon the tracheal lumen with the excision technic. Certain of these changes are depicted in figures 32 and 33.

Series 2:—The introduction of the cannula into the tracheotomy wound initi-

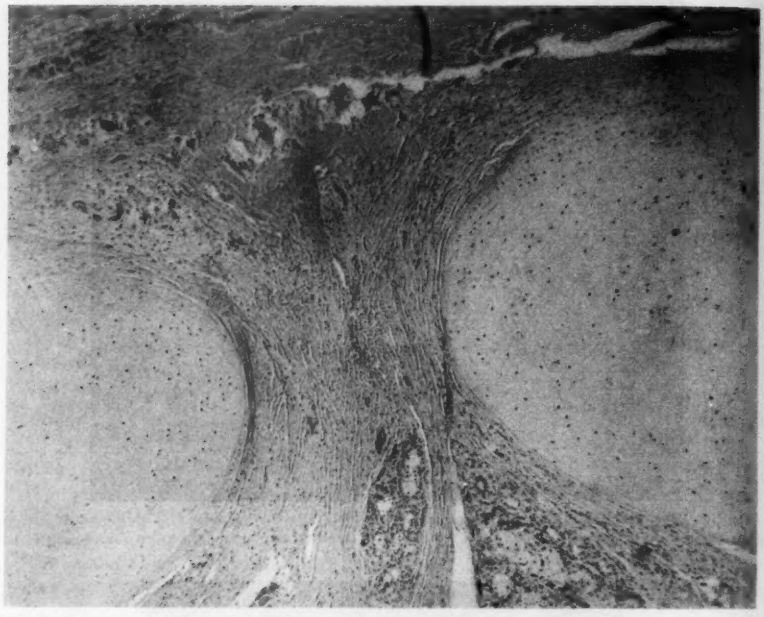

FIG. 32. Photomicrograph (× 30). Healed tracheotomy site after simple incision of the trachea. Note smoothly rounded, healed ends of cartilage and thin line of scar tissue between. Regeneration of submucosal glands is evident.

ated a series of changes which resulted almost invariably in a certain amount of stenosis. The degree of stenosis depended largely on the severity of the tissue reaction to the foreign body, and the length of time that the cannula was in place. The most consistent change noted was the early development of granulation tissue in and about the tracheotomy wound. The amount of granulations that developed did not appear to have any relationship to the type incision used, but was more closely related to the length of time the cannula was in place. Over a prolonged period this process often became extensive. When wound infection occurred, as happened in three animals, further tissue destruction took place and more granulation tissue resulted.

At the time the cannula was removed, a notation was made as to the presence of excess granulation tissue in and about the tracheotomy site. The presence of abnormal amounts of granulations was further substantiated by laryngoscopic and bronchoscopic examination in four of six animals in series 2 and 3 in whom such an observation had been made from inspection of the wound. These findings of infection and excess granulations were later correlated with the degree of stenosis found at postmortem examination.

After the cannula was removed, the granulations became converted to a scar which upon maturation induced shrinkage and distortion of the nearby tissues. Figures 34 and 35 indicate the scarring about the tracheotomy site that resulted

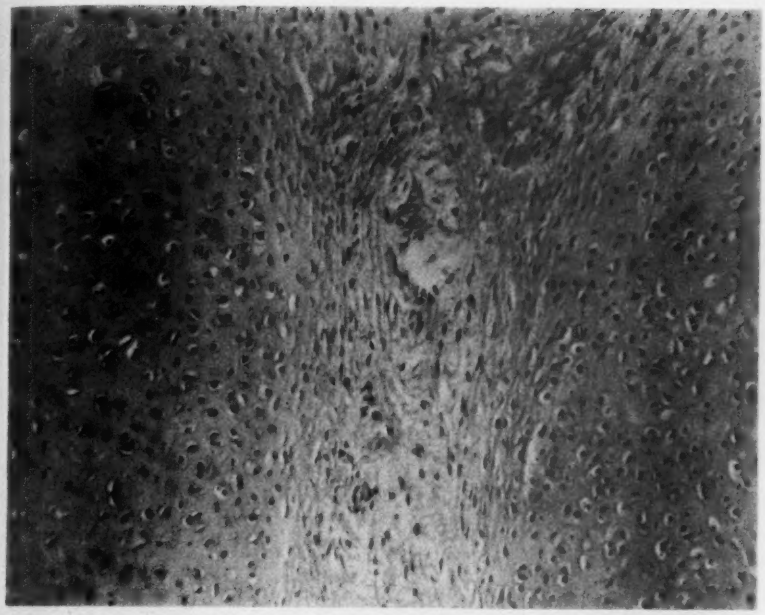

FIG. 33. Photomicrograph (× 105). Healed tracheotomy site after simple incision. Note the closely approximated ends of cartilage and the fine line of fibrosis between.

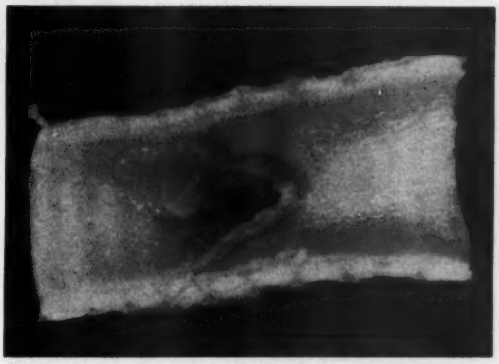

FIG. 34. Trachea of dog showing scar tissue about healed tracheotomy site. Tracheotomy has been reopened for measurement.

from these changes. On microscopic examination the site of the tracheotomy was marked by a layer of mature scar tissue which protruded into the lumen. The mucosal epithelium overlying this area consistently underwent squamous metaplasia. In most instances, a return to normal respiratory epithelium did not occur during the healing period.

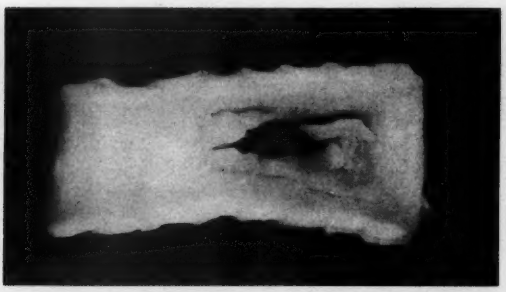

FIG. 35. Trachea of dog showing scar tissue about healed tracheotomy site. Tracheotomy has been reopened for measurement.

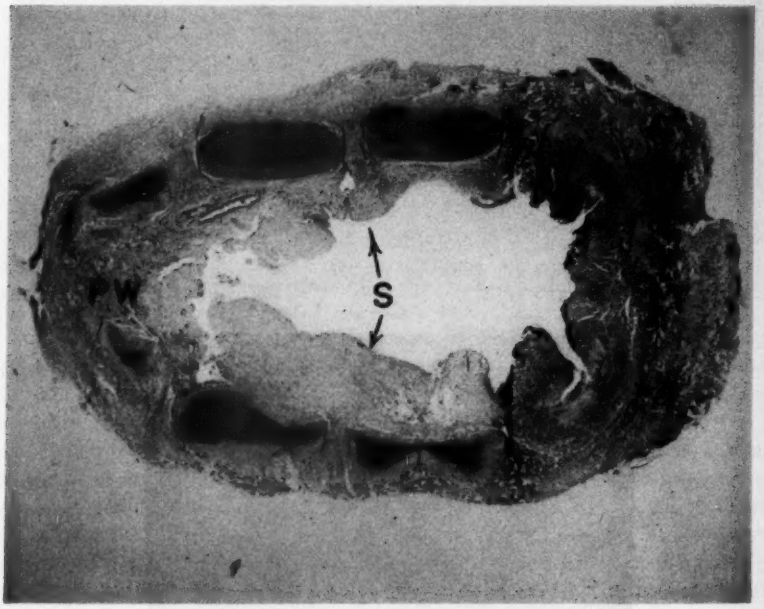

FIG. 36. Photomicrograph (× 5). Cross-section showing marked piling up of scar tissue (*S*) in tracheal lumen adjacent to tracheotomy site (*T*). Also note narrowing of posterior wall of trachea (*PW*).

When the cannula was placed through a slit in the trachea, distortion and buckling of the cartilages occurred. As previously pointed out, when the transverse slit was used, this distortion caused the cannula to rub on the anterior tracheal wall and produce an intolerable irritation. With the vertical slit, buckling of the cartilages was quite pronounced. Whether or not these changes became permanent could not be ascertained. It is suspected that they did not, since the width of the posterior wall on final healing was decreased as much with the

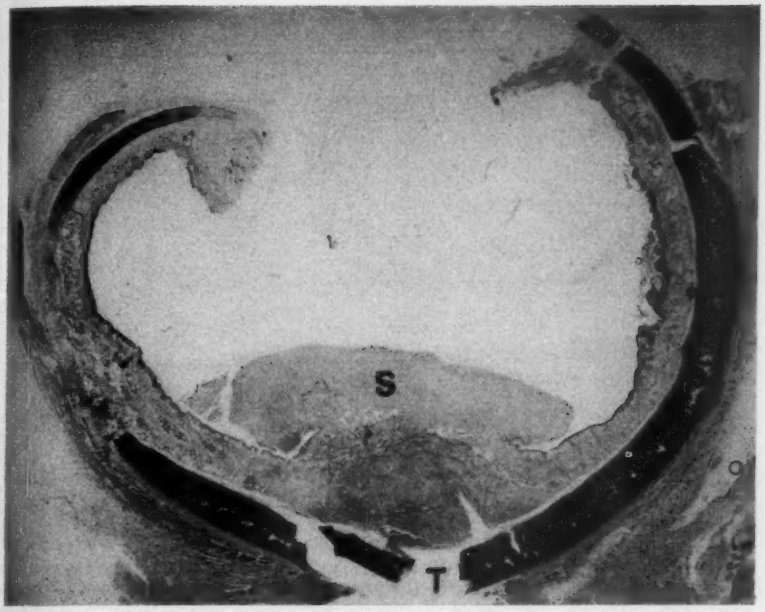

FIG. 37. Photomicrograph (× 5). Cross-section showing fibrous tissue encroachment (*S*) on lumen at healed tracheotomy site (*T*). Marked squamous metaplasia is present.

cruciate and window incisions as with the vertical slit. Once initial necrosis and absorption of cartilage about the cannula occurred, there did not appear to be any great difference in the appearance of the wound with any of the types of incisions used. During the time the cannula was in place additional loss of cartilage probably occurred, either from pressure necrosis or absorption by the inflammatory process. Permanent changes were produced which probably did not become corrected during the healing period. There was never any evidence that regenerating cartilage entered into the healing process. Most of these changes just described are shown in figures 36–42.

Series 3:—Changes similar to those just described for the experiments with the trachea also occurred when a cannula was introduced into the region of the cricoid cartilage. Marked erosion and distortion of the cartilage occurred in all animals in whom the cannula was placed in the cricothyroid space for over a 10-day period. If the cricoid was surgically cut or became eroded through by the tube, then there was a tendency for stenosis to develop from mechanical collapse of the airway in addition to that developing from the inflammatory reaction and granulation tissue surrounding the opening. This collapse not only produced a decrease in the size of the lumen but also, as determined by the measurements of the length of the larynx, a decrease in the over-all length. This decrease in

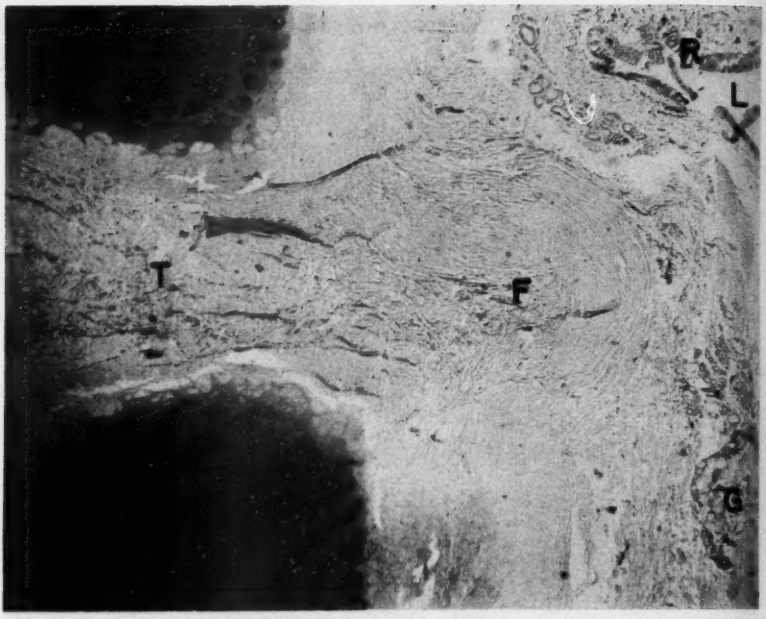

FIG. 38. Photomicrograph (× 15). Healed tracheotomy site (*T*) after use of cannula for short length of time. Note fibrous tissue (*F*) projecting into lumen (*L*) between cut ends of cartilage. The respiratory epithelium (*R*) and the submucosal glands (*G*) have regenerated and appear normal.

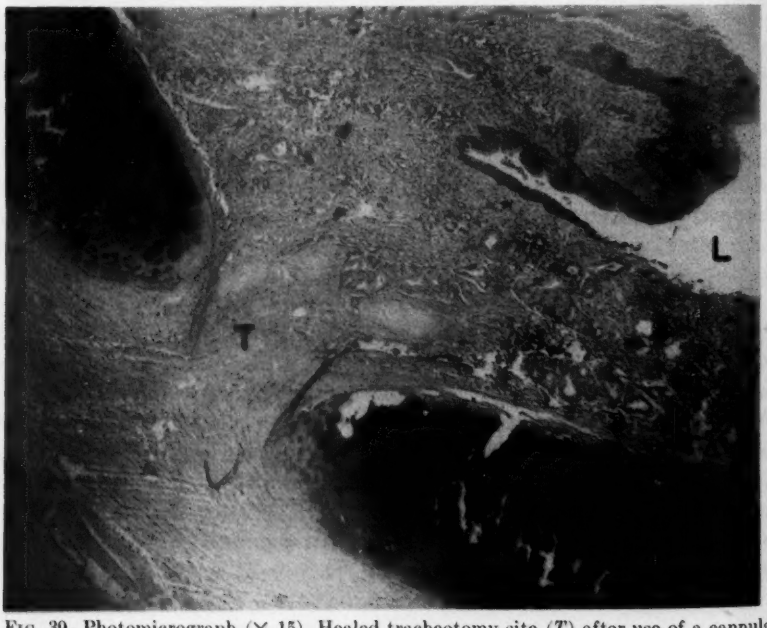

FIG. 39. Photomicrograph (× 15). Healed tracheotomy site (*T*) after use of a cannula. Note scar tissue and granulations encroaching on lumen (*L*). Marked squamous metaplasia (*SM*) is present.

FIG. 40. Photomicrograph (× 15). Deformed cartilage (*C*) adjacent to tracheotomy site is shown at left. Note the marked granulations and fibrous tissue (*F*) extending well into lumen of trachea (*L*). Marked squamous metaplasia (*SM*). Cannula was used for four months; this picture taken after four months' healing time was allowed.

FIG. 41. Photomicrograph (× 30). Deformed cartilage (*DF*) adjacent to healed tracheotomy site (*T*). Minimal scarring. Respiratory epithelium (*RE*) is regenerating. Cannula was worn for 20 days; healing, 40 days.

FIG. 42. Photomicrograph (× 30). Erosion of cartilage (*C*) adjacent to healed tracheotomy site from pressure of cannula. Cannula worn four months; healing, six months. Wound infection occurred and induced a marked proliferation of granulations and erosion of cartilage.

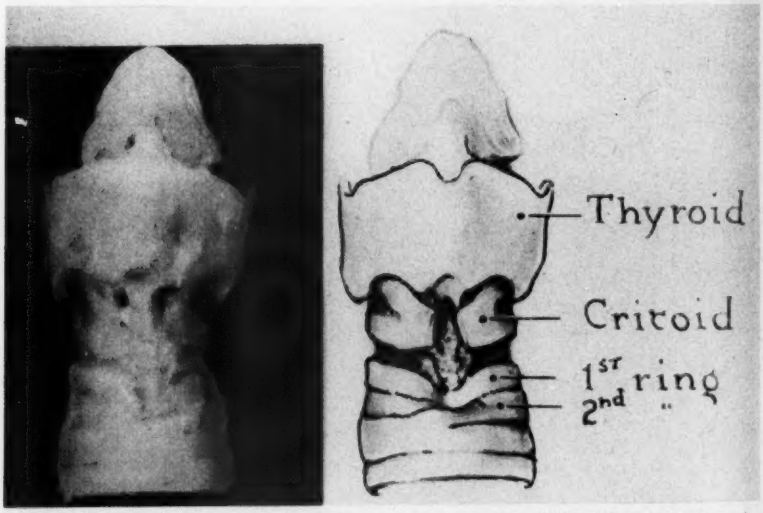

FIG. 43. Trachea and larynx of dog after cannula was placed through incision in cricoid cartilage. Note that cannula has eroded downward and partially through first tracheal ring. There is marked scarring and narrowing of the larynx at cricoid level.

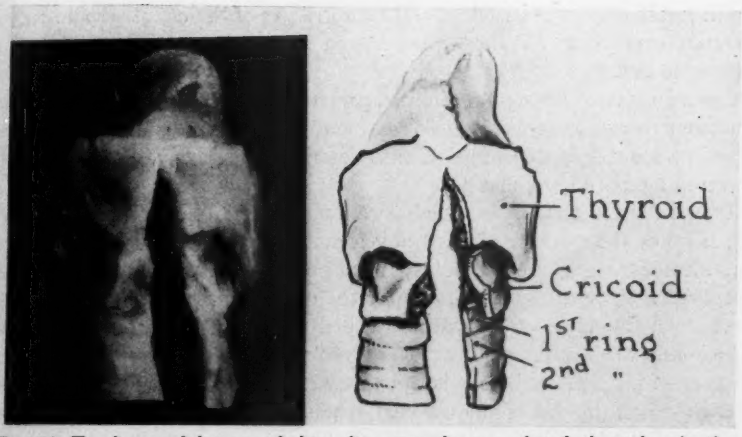

FIG. 44. Trachea and larynx of dog after cannula was placed through cricothyroid membrane for 30 days. Cannula has eroded through cricoid cartilage. There is complete loss of the cricothyroid space and overlapping of thyroid and cricothyroid cartilages and cricoid cartilage over first tracheal ring, resulting in a decrease in length of larynx. Marked granulations and scarring surround tracheotomy site and project into lumen of larynx. Specimen has been sectioned longitudinally to show these changes.

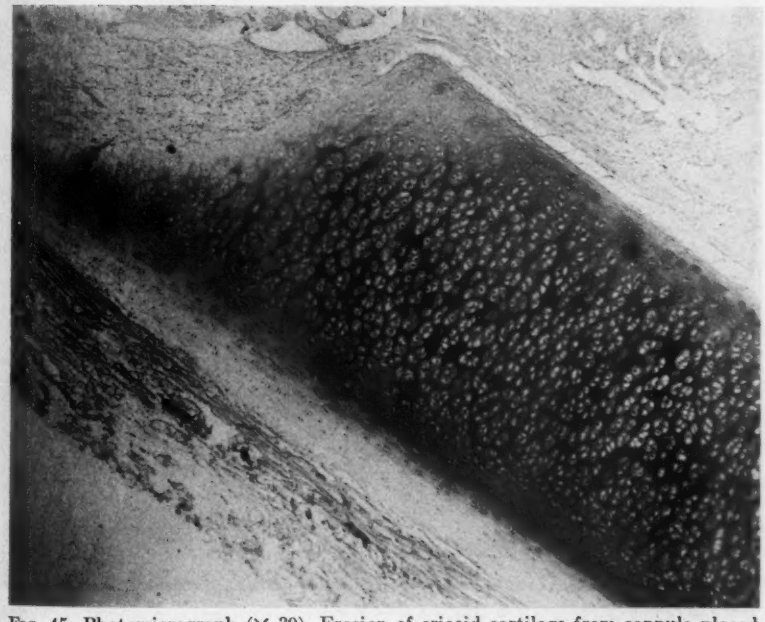

FIG. 45. Photomicrograph (× 30). Erosion of cricoid cartilage from cannula placed in cricothyroid space for 20 days.

length resulted from destruction and compression of the cricothyroid space and also from overriding of the deformed cricoid cartilage onto the first tracheal ring (figures 43 and 44).

The microscopic sections revealed a protrusion of scar tissue into the lumen, squamous metaplasis covering this scar, and erosion and distortion of the cartilages in a manner quite similar to that described previously. These changes are shown in figures 45, 46, and 47.

Except for the animals in which a cannula was placed through a transverse slit, none of the dogs manifested any signs of airway obstruction or stenosis, regardless of the degree of stenosis found at postmortem examination. All animals recovered their normal bark soon after the cannula became plugged or was removed. All the tracheotomy fistulas healed readily in seven days or less after the cannula was taken out. There was no relationship of the speed of healing to the type of incision used. This is to be expected since, as previously mentioned, after five days the size of the tracheal opening was approximately the same regardless of the type incision used. Since there was no opportunity to compare healing with the various types of incisions when the cannula was used for short periods, a series of 10 patients was selected to study this factor. There were four vertical incisions, four window incisions, and two cruciate incisions studied. The cannulas had been in place three to eight days. In vertical or cruciate incisions,

FIG. 46. Photomicrograph (× 15). Erosion of cricoid cartilage from pressure of cannula. Note granulation tissue with squamous metaplasia (*SM*) projecting into lumen (*L*) of larynx.

FIG. 47. Photomicrograph (× 30). Marked erosion and deformity of cricoid cartilage (*D*) adjacent to site of excision for placement of cannula (*S*). Cannula worn 30 days; healing, 60 days. Stenosis marked from collapse of cartilage and encroachment on lumen (*L*) by granulations.

present three to five days, the cessation of air leak after removal of the cannula occurred a day or two sooner than if the window incision had been employed. If the cannula was in place five days or longer, there was no difference in the time it took for the air leak to stop. All wounds healed readily within 7 to 10 days.

Interpretation and Discussion of Experimental Data

Analysis of the findings from tables 8, 9, and 10 and from the gross and microscopic examinations of the tracheotomy wound reveals that, in this experimental study, there were five major factors in the development of stenosis of either the larynx or trachea. These factors and their relationship to the degree of stenosis developing in each of the 28 experimental animals are shown in table 11. In order of relative importance, these factors are: (1) presence of a cannula; (2) development of infection or excessive granulation tissue; (3) length of time cannula is in place; (4) location of incision; and (5) type of incision.

A comparison of the effect of each of these factors in causing stenosis is summarized in table 12. This comparison reveals that the degree of stenosis was definitely increased when the cannula was employed, as opposed to its not being used; that stenosis was augmented with prolonged use of the cannula; and that stenosis was intensified when infection or excessive granulations developed.

TABLE 11

The relationship of certain factors to the development of stenosis

Dog No.	Type of Incision	Use of Tube	Time* Factor	Infection Granulation	Index of Stenosis	Degree of Stenosis
			days			
1	Vertical	No	30	No	12	None
2	Transverse	No	30	No	5	None
3	Cruciate	No	30	No	15	None
4	Window	No	30	No	18	None
5	Vertical	No	60	No	24	?
6	Transverse	No	60	No	5	None
7	Cruciate	No	60	No	11	None
8	Window	No	60	No	24	?
9	Vertical	Yes	10/20	Yes	65	Moderate
10	Transverse	Yes	10/20	—	—	—
11	Cruciate	Yes	10/20	No	60	Moderate
12	Window	Yes	10/20	No	40	Minimal
13	Vertical	Yes	20/40	No	50	Moderate
14	Transverse	Yes	20/40	—	—	—
15	Cruciate	Yes	20/40	No	43	Minimal
16	Window	Yes	20/40	Yes	50	Moderate
17	Vertical	Yes	30/60	No	64	Moderate
18	Cruciate	Yes	30/60	Yes	50	Moderate
19	Window	Yes	30/60	Yes	64	Moderate
20	Vertical	Yes	120/180	Yes	73	Marked
21	Cruciate	Yes	120/180	Yes	88	Marked
22	Window	Yes	120/180	Yes	61	Moderate
23	Cricoid	Yes	10/20	No	38	Moderate
24	Cricothyroidotomy	Yes	10/20	No	27	Minimal
25	Cricoid	Yes	20/40	No	33	Moderate
26	Cricothyroidotomy	Yes	20/40	Yes	50	Marked
27	Cricoid	Yes	30/60	Yes	53	Marked
28	Cricothyroidotomy	Yes	30/60	Yes	45	Moderate

* See tables 8, 9, and 10.

These three factors were closely interrelated in that the presence of the cannula incited the formation of granulation tissue, and the longer the cannula was in place the greater the tendency for these granulations to become excessive. If a wound infection developed, then the degree of stenosis was further increased. For example, those animals (dogs 9, 11, and 21) that developed a wound infection showed a much greater index of stenosis than the other animals in their group. This is believed to account for the fact that the average index of stenosis was greater for the three animals (dogs 9, 11, and 12) in group 1, series 2, than for the three animals (dogs 13, 15, and 16) in group 2, series 2, although the time factor for the former group was one-half that of the latter. The potency of wound infection as a factor causing stenosis is further substantiated by the fact that the animal (dog 21) that had the more severe infection also had the highest index of stenosis recorded for the entire experimental series.

TABLE 12

Comparison of the effect of the chief factors in the development of stenosis

Factor	Number of Dogs	Average Index of Stenosis
Cannula		
Without	8	14
With	14	56
Granulations		
Excessive	7	68
Normal	5	47
Time cannula used		
Less than 30 days	6	53
More than 30 days	6	67
Types of incisions		
Vertical	4	63
Cruciate	4	60
Window	4	54

No correlation could be established between the type of incision used and the degree of stenosis that developed. The average index of stenosis slightly favored the window incision, but the difference was not statistically significant. There was no evidence that buckling or distortion of the cartilages from the cannula at the time of the original operation had any long-term effect on the development of stenosis. Deformity of the cartilages was more often related to erosion from constant pressure of the cannula and from absorption of cartilage into the chronic inflammatory process about the opening.

A contrast between the effect of the laryngeal and tracheal locations for tracheotomy is not included in table 12, since, as mentioned previously, the data obtained did not offer a good basis for statistical comparison. However, certain conclusions could be drawn in this regard. By comparison with the ordinary location for tracheotomy, operations in the cricoid area caused stenosis to develop in more animals sooner and to a more marked degree. Only one of the six animals (dog 24) failed to develop at least a moderate degree of stenosis. Stenosis developed because of encroachment on the lumen by granulation tissue and scar and from deformity of the cartilaginous framework by fibrosis in a manner similar to the tracheal operations. In addition, when the cricoid cartilage was cut or eroded through, an actual collapse of the lower part of the larynx seemed to occur.

Physiologic Experiments

The use of the tracheotomy opening as a vent to prevent aspiration of pharyngeal secretions in respirator patients, to prevent the transmission of increased intrathoracic pressure to the cranial cavity in head injury patients, and to prevent disruption of a precarious bronchial stump closure from closed glottis pressure has been mentioned previously. Two experiments were performed in this regard. The first experiment was designed to test the efficiency of the tracheotomy opening in preventing transmission of increased intrathoracic pressure to the cranial

cavity. Measurements of spinal fiuid pressure were used as the basis for the experimental conclusions. The second experiment was designed to test the use of the tracheotomy opening as a vent in preventing simulated closed glottis pressure on a bronchial stump closure. Underwater air leak and direct pressure readings from the bronchial stump were used as the basis for the experimental conclusions.

First physiologic experiment. Two animals were used in this experiment concerned with spinal fluid pressures. A problem that presented itself immediately was how to produce sustained or recurrent increased intrathoracic pressure sufficient to produce a measurable change in spinal fluid pressure. The answer to this problem came quite by accident when the experimenter noticed that certain of the dogs under light anesthesia manifested a grunting type of whine associated with forced expiration. Measurement of the spinal fluid pressure under these conditions revealed extremely abnormal pressures suitable for the purposes of this experiment.

In the first animal, a tracheotomy was performed and the cannula was plugged with a cork. The animal was then turned partially onto its side and a 23-gauge needle was introduced into the subarachnoid space of the spinal cord in the lumbar region at the level of the iliac crest. The needle was connected to a standard spinal fluid manometer filled with saline. The range of the manometer gauge in mm. of water was from zero to 300. On opening the fluid system, the range of spinal fluid pressure was from 120 to 150 mm. of water. The highest reading coincided with the expiratory grunt of the dog. When the tracheotomy was unplugged, there was a drop in pressure, but only to 110 mm. of water, much less than was expected. In fact, the initial pressure was not so great as anticipated. Because of technical difficulties with the manometer system, no further readings were obtained. Two sources of possible error were suspected. First, there had been leakage of about 5 to 10 cc. of spinal fluid. Second, there was a small air leak about the tracheotomy cannula.

In the second animal, the trachea was exposed, but not incised, and the manometer was connected more carefully to the spinal needle. The initial pressure range was from 190 to 220 mm. of water. A small incision was made into the trachea so that a minimal air leak was established. The pressure immediately fell to about 150 mm. of water (range 164 to 130). Upon opening the trachea to the full size of a tracheotomy cannula, the pressure fell to 110 millimeters of water and showed very little fluctuation on respiration. When the tracheal opening was closed with the finger, the spinal fluid pressure immediately began to rise abruptly with each expiratory grunt and the wide swing in pressure during the two phases of respiration was again noted. The entire sequence was repeated once more with the same results. The experiment was terminated.

It is believed that this simple experiment corroborates the contention that a tracheotomy opening serves as an efficient vent to prevent the transmission of increased intrathoracic pressure to the cranial cavity.

Second physiologic experiment. One animal was used in this experiment concerned with the testing of a tracheotomy opening as a vent in the prevention of closed glottis pressure on a bronchial stump closure.

Since the animal was to be sacrificed, no sterile precautions were taken. A right

posterolateral thoracotomy was performed through the fourth intercostal space. Respiratory excursion was maintained with an endotracheal tube and automatic respirator. The right main-stem bronchus was dissected free from the pulmonary vessels and vena cava and clamped with crushing forceps to injure the bronchial wall. The bronchus was then divided at the site of injury and the stump closed with interrupted 3–0 silk sutures. A 17-gauge needle was placed into the bronchial stump about 1 cm. proximal to the site of closure and connected to a water manometer. The endotracheal tube was advanced until the tip was near the carina of the trachea. The pharynx and larynx were then packed tightly with wet gauze to form an air seal. The automatic respirator was adjusted until a range of pressure, from 4 to 8 cm. of water, was being obtained on the manometer connected to the bronchial stump. The right pleural space was then flooded with saline until the site of bronchial closure was covered. The endotracheal tube was then disconnected from the automatic respirator and connected to an inflatable rubber anesthesia bag filled with air. Coughing was simulated by a sudden, forceful manual compression of the bag. Momentary pressures in the bronchial stump were obtained in the range of 30 to 34 cm. of water and leakage of air was obtained from the bronchial stump through the suture line. A 17-gauge needle was placed into the cervical trachea as a vent. The maximum pressure obtainable with sustained compression of the anesthetic bag was only 18 to 22 cm. of water, and the air leak through the suture line was greatly diminished. When a ½-cm. hole was made in the cervical trachea the pressures obtained in the bronchial stump registered only 5 to 10 cm. of water and then only for an instant before dropping to zero. The bronchial stump could not then be made to leak until a small hole was made in it.

It is believed that this experiment demonstrates that a tracheotomy opening will greatly decrease closed glottis pressure and will greatly diminish the pressure exerted on the bronchial wall by coughing. During the process of coughing the pulmonary tree becomes a closed, but elastic system upon which maximum pressure is brought to bear at the instant just before the glottis is opened. It is obvious that this pressure will escape at the weakest or most open point in the system. The vent in this closed system provided by the tracheotomy opening should efficiently prevent the buildup of sufficient intrapulmonary pressure to cause disruption of a bronchial stump closure. It should be pointed out that the decrease in intrapulmonary pressure following tracheotomy is also one of physiologic disadvantages of the operation. The effectiveness of the cough may be so greatly reduced that the patient is unable to bring up distally located secretions to within reach of the aspirating catheter. The quality of cough may be greatly enhanced by simply blocking the tracheotomy opening for a moment, which allows intrapulmonary pressure to develop when the glottis is closed.

Summary of Experimental Material and Conclusions

1. The historic interest in healing of the tracheotomy wound has been discussed and the major experimental studies have been summarized to the present date.

2. The results of an experimental study designed to test the effect of various

factors in the development of either laryngeal or tracheal stenosis after tracheotomy have been presented. Emphasis was placed on the study of stenosis after relatively long-term healing. So far as is known, a similar study has not been previously undertaken.

3. The chief factors in the development of stenosis were found to be: (1) presence of the tracheotomy cannula, (2) length of time the cannula was in place, (3) the development of wound infection or excessive granulation tissue, (4) location of incision, and (5) type of incision.

4. The major causes of tracheal stenosis after tracheotomy were the prolonged use of the cannula and the development of excessive granulations in and about the tracheotomy opening. These two factors were found to be closely related. If wound infection developed, the additional destruction of tissue and cartilage induced more granulation tissue and, subsequently, more stenosis.

5. The major causes of laryngeal stenosis were the same as for tracheal stenosis. In addition, the factor of mechanical collapse of the lower part of the larynx was added when the cricoid cartilage was cut or eroded through. When tracheotomy was performed in the cricoid cartilage area, stenosis seemed to develop more readily and to a greater degree than for the usual tracheotomy location. In fact, only one animal failed to develop at least moderate to marked stenosis.

6. The type of tracheotomy incision seemed to have no effect on the development of long-term stenosis. The fact that the placing of a cannula through a slit induces buckling of the cartilages did not seem to be a major factor in the development of permanent distortion of the cartilage.

7. The transverse tracheal incision was found to be entirely unsatisfactory because of the immediate development of anteroposterior angulation of the trachea and rubbing of the end of the cannula on the anterior tracheal wall. This fact is more of historic than clinical interest, since, so far as is known, such an incision is no longer employed. However, it is conceived that a poorly placed transverse skin incision might induce similar displacement of the cannula and cause rubbing of the cannula on the tracheal wall.

8. Two experiments were performed to test the physiologic changes in pressure dynamics within the respiratory tree following tracheotomy. It was discovered that the tracheotomy opening serves as a very efficient vent in reducing the transmission of increased intrathoracic pressure to the cranial cavity and in reducing closed glottis pressure on a bronchial stump closure.

9. Certain conclusions of clinical interest were drawn from this experimental study. First, the development of laryngeal or tracheal stenosis is dependent primarily on the types of changes in the tracheotomy wound that would occur with prolonged use of a neglected cannula. Again, the importance of proper aftercare of a tracheotomy is brought to mind, and the ill effects of unnecessarily prolonged use of the cannula are reemphasized. Second, there did not appear to be any experimental basis for favoring any one type of incision into the trachea. The excision technic, or window incision, was of no advantage insofar as the prevention of stenosis was concerned. However, there were no disadvantages noted experimentally for this technic. The decision as to what type of tracheal

incision is to be used can be made on clinical grounds alone. Third, there seemed to be an increased hazard of laryngeal stenosis when the cannula was placed through or near the cricoid cartilage. Cricothyroidotomy is not believed to be a safe operation from this standpoint. The operation is especially unsafe if the cricoid cartilage is injured. Of the six animals tested with this type of operation, the only animal that failed to develop an appreciable degree of stenosis was the one in which a cannula was placed through the cricothyroid space for a period of 10 days. Whether or not it is safe for the patient to wear a cannula in this location for periods of less than 10 days was not determined.

CHAPTER V. SUMMARY AND CONCLUSIONS

1. An historic, clinical, and experimental investigation of tracheotomy has been presented.

2. The story of tracheotomy has been portrayed from its inception to the present time, with particular attention given to the reluctant acceptance and fear of the operation in centuries past, as contrasted to the wide application of tracheotomy in nearly every type of ventilatory distress today.

3. A detailed clinical analysis of the indications, special uses, technic, complications, and results of 310 tracheotomies, performed in 300 patients, has been presented. Emphasis was placed on the over-all increased use of the operation as depicted in these consecutive, unselected cases, the largest such series yet reported.

4. The chief reason for the increase in scope and number of the indications was the recognition of the value of tracheotomy for relief of retained secretions and for other physiologic advantages, rather than for its classic use in bypassing a mechanical obstruction of the airway. In addition, many advantages and special uses for tracheotomy, not previously stressed, were uncovered. Numerous clinical examples demonstrating the advantages of tracheotomy for all these indications have been presented and discussed.

5. An analysis of the deaths and complications due to tracheotomy revealed that most of these errors were avoidable. Delay in the prompt performance of a clearly indicated operation and faulty aftercare were responsible for most of the deaths due to tracheotomy. Complications were more frequent in children and with emergency operations, and more often occurred postoperatively than during the operation. The positive steps that can be taken to avoid these mistakes have been outlined and discussed.

6. The technic of tracheotomy has been considered from a clinical, anatomic, and experimental viewpoint. The clinical study revealed that there are many advantages of the technic of tracheotomy in which excision of a portion of the anterior tracheal wall is practiced. The anatomic studies on living and cadaver subjects demonstrated several important considerations in the surgical approach to the trachea with reference to the position of the patient for operation, the choice of skin incision, and the method of handling the thyroid isthmus.

7. The results of an experimental study in the dog comparing the types and locations for tracheotomy incisions have been presented. This study revealed

that there is no difference in healing with any of the common methods of incising the trachea and that stenosis or other deformity of the airway was due to prolonged use of the cannula and the formation of excessive granulation tissue about the tracheotomy opening. These factors resulted in necrosis and deformity of cartilage and dense fibrosis at the site of operation. Experimental operations performed through or near the cricoid cartilage yielded a higher incidence and degree of stenosis than did operations at the usual tracheotomy site. For this reason, cricothyroidotomy is not believed to be a safe operation, and is recommended for unusual emergencies only.

8. A recommended technic for elective tracheotomy based on these clinical, anatomic, and experimental studies has been presented. This technic entails a transverse skin incision, division rather than retraction of the thyroid isthmus, and excision of a piece of the anterior tracheal wall. No disadvantages, complications or delay in healing were occasioned by the use of this technic. The usual technic for tracheotomy, consisting of a vertical skin incision and vertical incision into the trachea, was demonstrated to have several disadvantages and hazards.

9. It may be concluded that tracheotomy is a singularly safe and efficient means of saving life, reducing morbidity, and simplifying many problems of management in a wide range of common diseases and injuries. The fact that over one-fourth of the 300 patients in the clinical study owed their life to tracheotomy speaks well for the present-day widespread use of the operation.

10. This clinical and experimental study of tracheotomy has been presented in the hope that it might be a substantial contribution to the treatment of many types of ventilatory deficiencies which would be fatal without the use of this valuable procedure. It seems certain that this unique operation, which has no counterpart for versatility in the entire field of surgery, will become even more widely used in the future, once the clinical advantages and safeguards of technic and aftercare become better recognized.

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NOTE: References 17, 27, 118, 180, 241, 248 and 254 are incomplete. However, any further information desired may be abtained from The Armed Forces Medical Library, Washington, D.C. using the reference as given.